CSI – Montana Floodplains

The Challenges of Developing Duplicate and Corrected Effective Models.

DOWL

MONTANA MDT DEPARTMENT OF TRANSPORTATION

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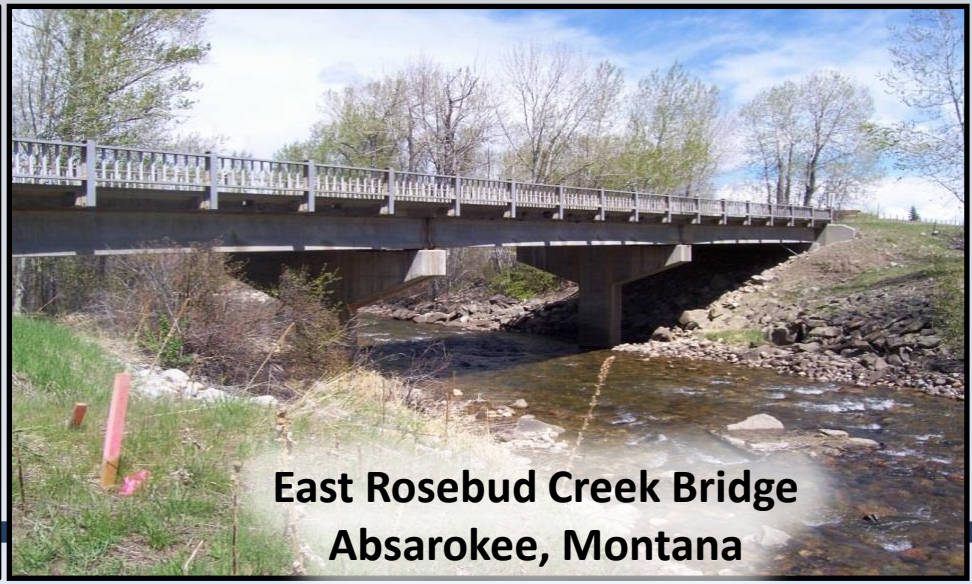
Red Rock Coulee Bridge
Chinook, Montana



East Rosebud Creek Bridge
Absarokee, Montana

FEMA Hydraulic Modeling Procedures

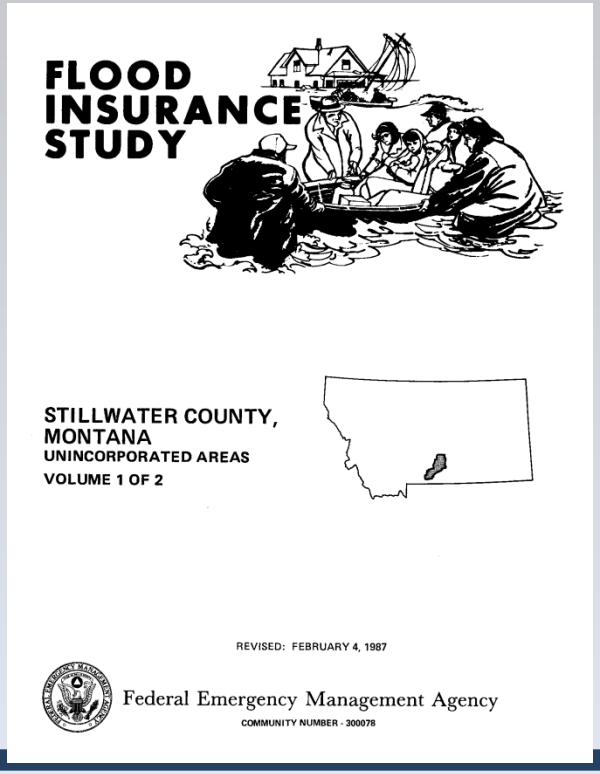
- DUPLICATE EFFECTIVE MODEL
  - Updating the effective model to current modeling software
- CORRECTED EFFECTIVE MODEL
  - Fixing errors, updating topography, and adding new XS
- EXISTING/PRE-PROJECT CONDITIONS MODEL
  - Adding man-made changes since effective model
- PROPOSED/POST-PROJECT CONDITIONS MODEL
  - Evaluating the hydraulic impacts of your project

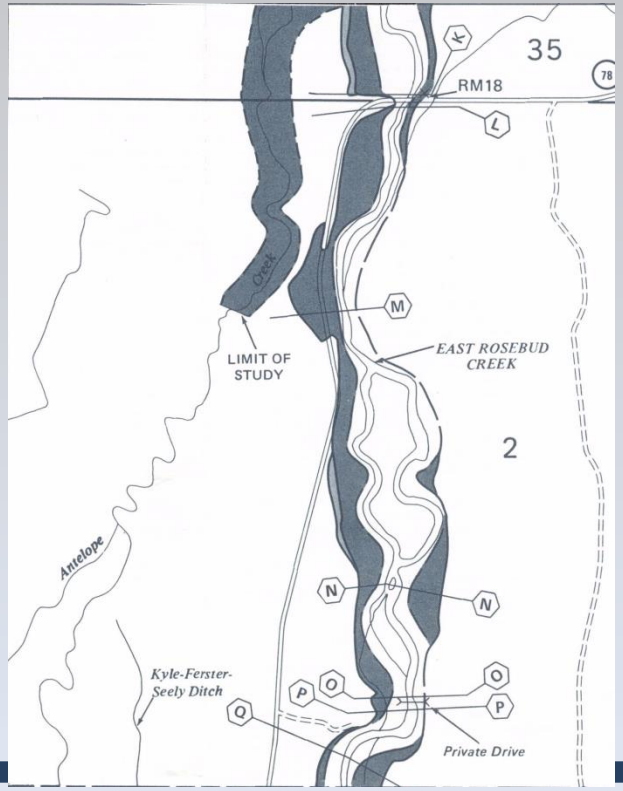
History of Montana Effective Models

- EFFECTIVE MODELS IN MONTANA
  - Big push in the 1970s and 1980s for floodplain mapping
  - Majority of the effective models are over 30-years old
  - Typical WSP-2, WSPRO, or HEC-2 models
- WHAT YEAR WAS HEC-RAS 1.0 RELEASED?
  - 1995 – Yes, 21-years old
  - HEC-RAS 5.0 was just released!
- TECHNOLOGY & AVAILABLE DATA
  - Advancements make it way easier to model today
  - Models developed on limited data
  - File storage was hard copies, no electronic file system

Resources to Developing Duplicate Effective Models

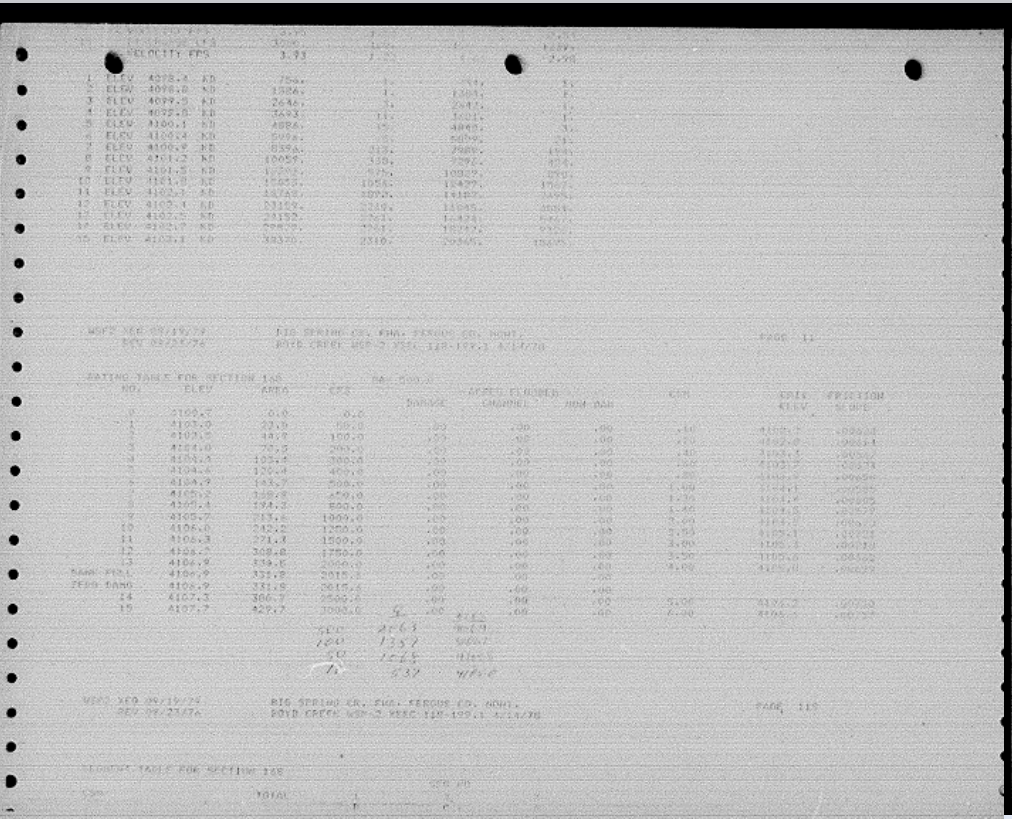
- WHAT ARE YOU TYPICALLY GIVEN?
  - HEC-2, WSP-2, WSPRO input and results files
  - Limited documentation from the Flood Insurance Report
  - Effective FIRM Maps

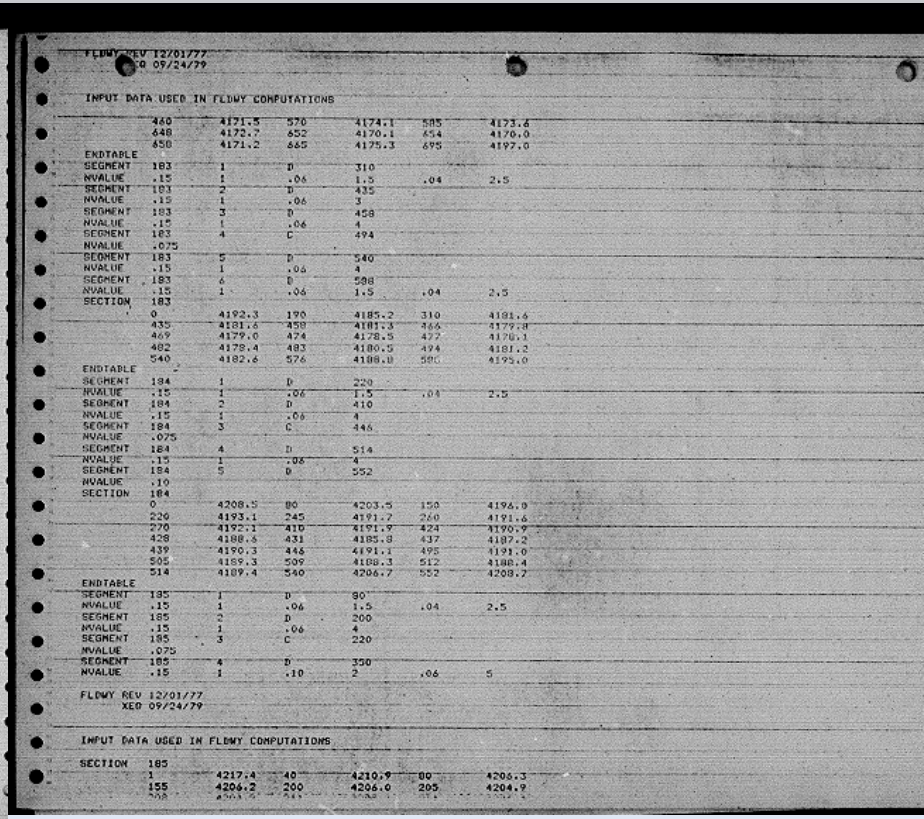




Model Input and Result

- FADED MICROFICHE COPIES
  - Hard to read / Missing or Cutoff pages
  - Need to understanding the coding
  - Hand written notes/cross outs
  - Additional cross sections not showing up in the FEMA maps





FLDWY REV 12/01/77
XEQ 09/24/79

INPUT DATA USED IN FLDWY COMPUTATIONS

	440	4171.5	570	4174.1	585	4173.6
	648	4172.7	652	4170.1	654	4170.0
	658	4171.2	665	4175.3	695	4197.0
ENDTABLE						
SEGMENT	183	1	D	310		
NVALUE	.15	1	.06	1.5	.04	2.5
SEGMENT	183	2	D	435		
NVALUE	.15	1	.06	3		
SEGMENT	183	3	D	458		
NVALUE	.15	1	.06	4		
SEGMENT	183	4	C	494		
NVALUE	.075					
SEGMENT	183	5	D	540		
NVALUE	.15	1	.06	4		
SEGMENT	183	6	D	588		
NVALUE	.15	1	.06	1.5	.04	2.5
SECTION	183					
	0	4192.3	190	4185.2	310	4181.6
	435	4181.6	458	4181.3	466	4179.8
	469	4179.0	474	4178.5	477	4178.1
	482	4178.4	483	4180.5	494	4181.2
	540	4182.6	576	4188.0	580	4195.0
ENDTABLE						
SEGMENT	184	1	D	220		
NVALUE	.15	1	.06	1.5	.04	2.5
SEGMENT	184	2	D	410		
NVALUE	.15	1	.06	4		
SEGMENT	184	3	C	446		
NVALUE	.075					
SEGMENT	184	4	D	514		
NVALUE	.15	1	.06	4		
SEGMENT	184	5	D	552		
NVALUE	.10					
SECTION	184					
	0	4208.5	80	4203.5	150	4196.0
	220	4193.1	245	4191.7	260	4191.6
	270	4192.1	410	4191.9	424	4190.9
	428	4188.6	431	4185.8	437	4187.2
	439	4190.3	446	4191.1	495	4191.0
	505	4189.3	509	4188.3	512	4188.4
	514	4189.4	540	4206.7	552	4208.7
ENDTABLE						
SEGMENT	185	1	D	80		
NVALUE	.15	1	.06	1.5	.04	2.5
SEGMENT	185	2	D	200		
NVALUE	.15	1	.06	4		
SEGMENT	185	3	C	220		
NVALUE	.075					
SEGMENT	185	4	D	350		
NVALUE	.15	1	.10	2	.06	5

FLDWY REV 12/01/77
XEQ 09/24/79

INPUT DATA USED IN FLDWY COMPUTATIONS

SECTION	185					
	1	4217.4	40	4210.9	80	4206.3
	155	4206.2	200	4206.0	205	4204.9

Flood Insurance Study Report

- LIMITED DOCUMENTATION
  - Who performed the evaluation
  - Hydrologic Analysis Section
  - Hydraulic Analyses Section
  - Floodway Tables
  - Flood Profiles

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY	INCREASE
East Rosebud Creek								
A	1,020	632	1,824	2.9	4,195.2	4,195.2	4,195.7	0.5
B	1,480	285	704	6.8	4,203.4	4,203.4	4,203.9	0.5
C	1,560	366	1,534	3.1	4,206.0	4,206.0	4,206.5	0.5
D	3,000	122	715	6.7	4,222.9	4,222.9	4,223.4	0.5
E	5,100	731	2,711	1.8	4,253.6	4,253.6	4,254.1	0.5
F	8,700	767	1,949	2.4	4,295.3	4,295.3	4,295.8	0.5
G	11,460	452	825	5.8	4,333.3	4,333.3	4,333.8	0.5
H	14,340	286	1,138	4.2	4,368.0	4,368.0	4,368.5	0.5
I	17,000	123	598	8.0	4,412.8	4,412.8	4,413.3	0.5
J	19,360	437	1,489	3.2	4,446.6	4,446.6	4,447.1	0.5
K	21,260	356	1,108	4.1	4,470.6	4,470.6	4,471.1	0.5
L	21,340	111	750	6.1	4,474.3	4,474.3	4,474.8	0.5
M	23,080	133	846	5.4	4,496.0	4,496.0	4,496.5	0.5
N	25,600	253	1,341	3.4	4,528.0	4,528.0	4,528.5	0.5
O	26,500	381	1,098	4.2	4,540.7	4,540.7	4,541.2	0.5
P	26,600	410	817	5.6	4,542.1	4,542.1	4,542.6	0.5
Q	27,260	258	853	5.4	4,549.1	4,549.1	4,549.6	0.5

[1]Feet Above Confluence With West Rosebud Creek and Rosebud Creek

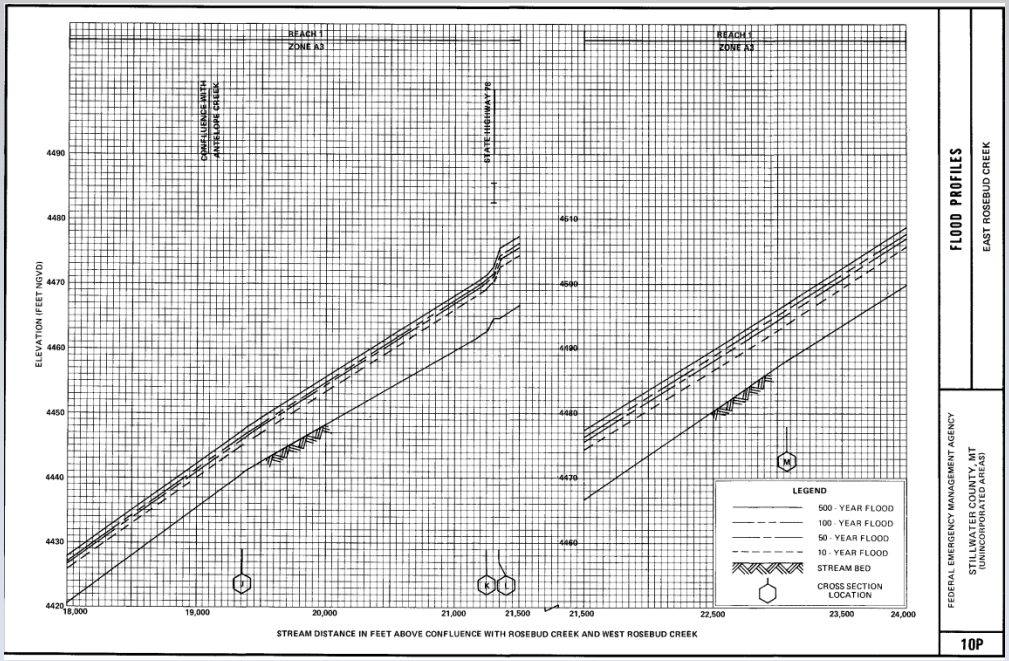
TABLE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

STILLWATER COUNTY, MT
(UNINCORPORATED AREAS)

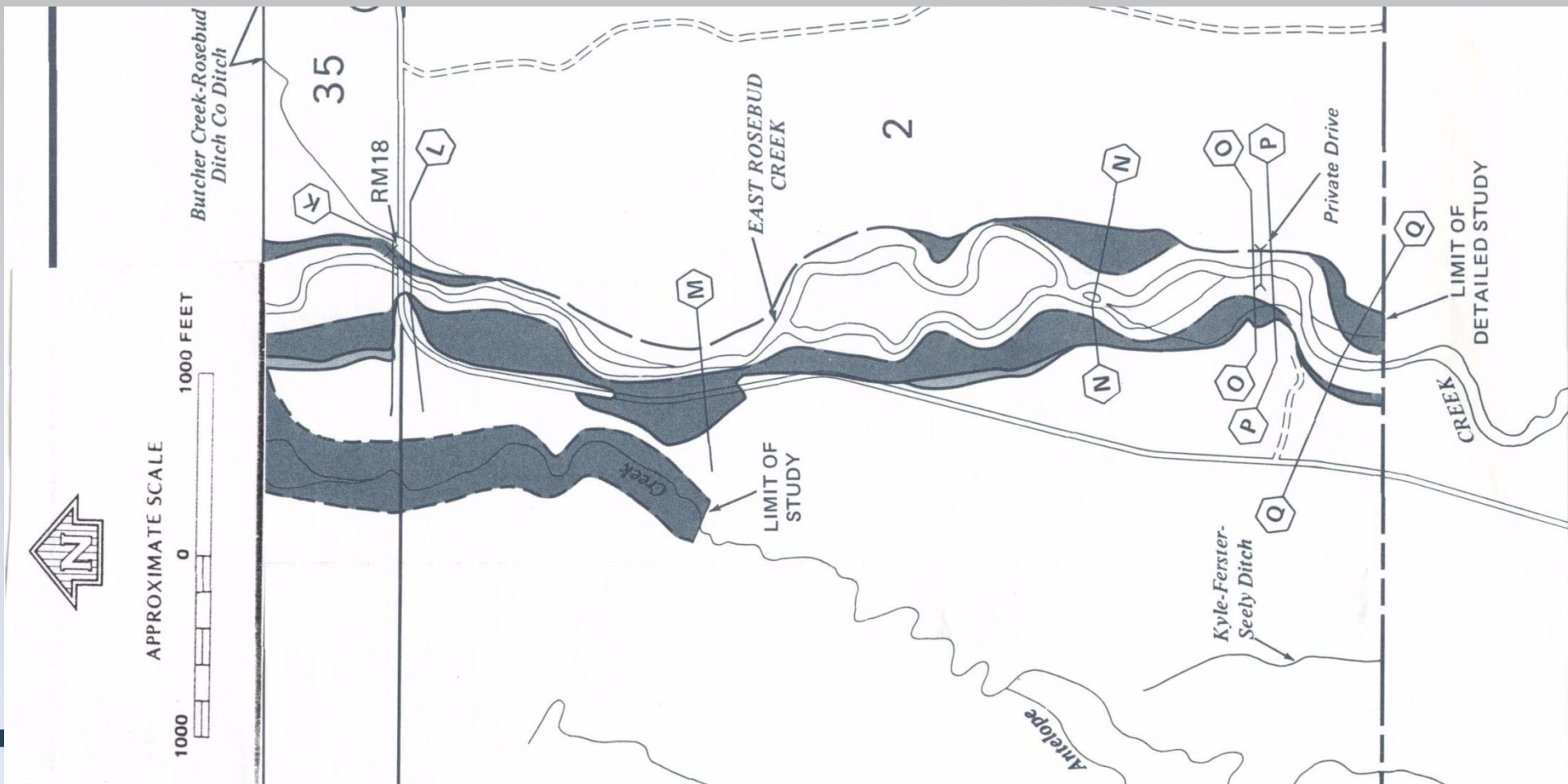
FLOODWAY DATA

EAST ROSEBUD CREEK



Flood Insurance Rate Maps

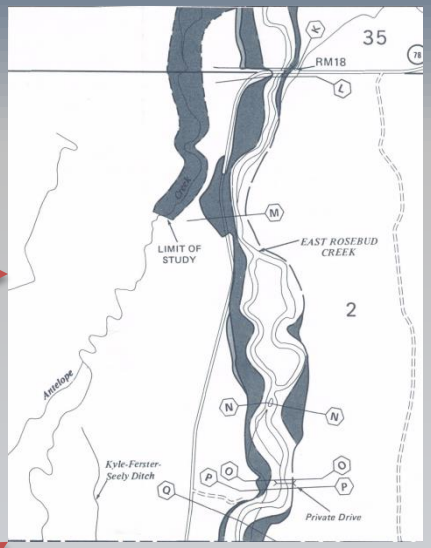
- PLAN VIEW LAYOUT OF THE MODEL
  - Cross section locations for letter crossings
  - Bridge crossings locations



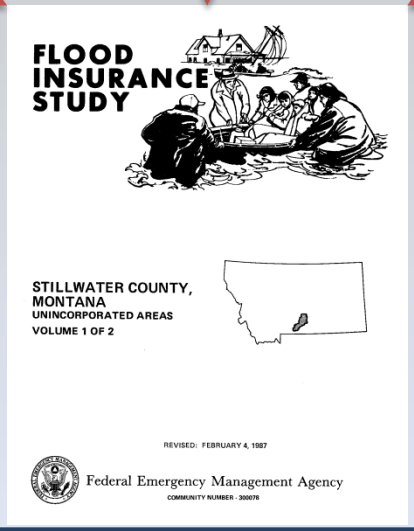
Developing the Duplicate Effective Model

Model Inputs & Results

DUPLICATE EFFECTIVE MODEL



FIRM Maps



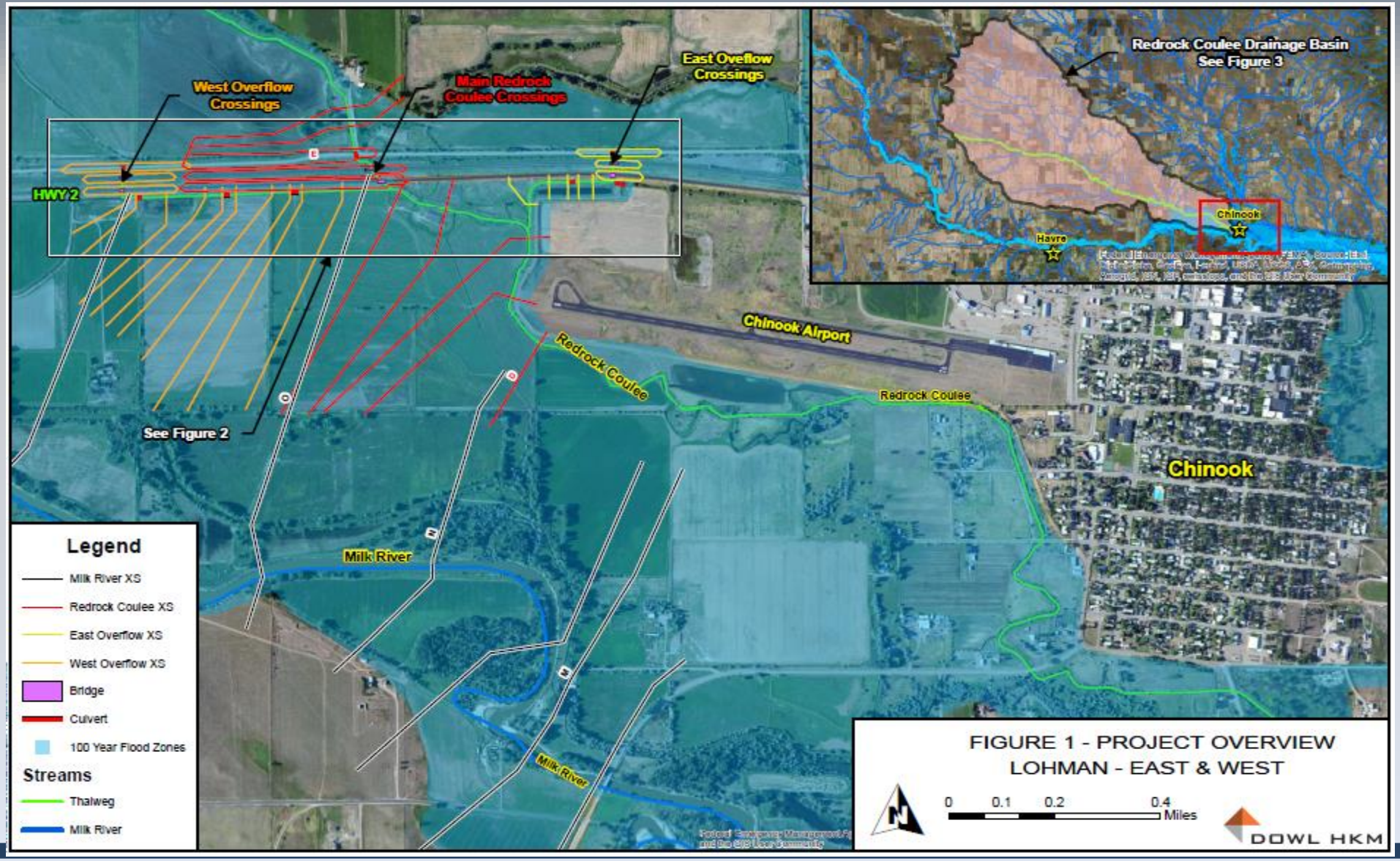
Lohman – East & West
Redrock Coulee Bridge Replacement

- PROJECT OVERVIEW
  - Goal: Replacement of 3 MDT Bridges Along Highway 2
  - Location: Immediately West of Chinook, MT

- WHY REPLACE THE BRIDGES???
  - Road Widening = Improve Public Safety
  - Existing Bridges are Wooden Structures
  - All 3 Bridges Are At The End Of Their Service Life

- PROJECT CHALLENGES
  - Located in a Detailed Floodplain
  - Hydrology
  - Stream/Reach Lengths
  - Complex Flow Splits

Lohman – East & West
Redrock Coulee Bridge Replacement



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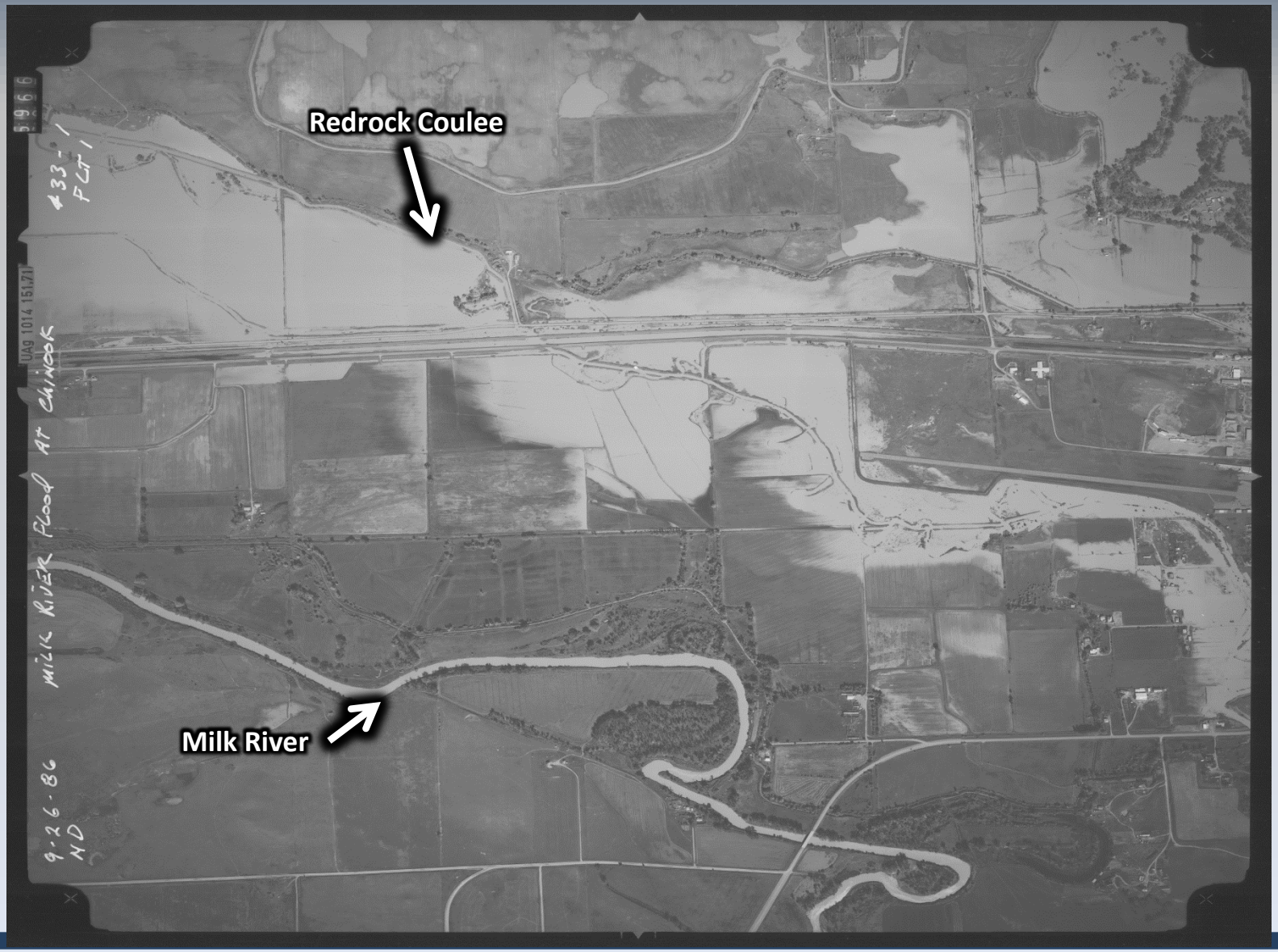
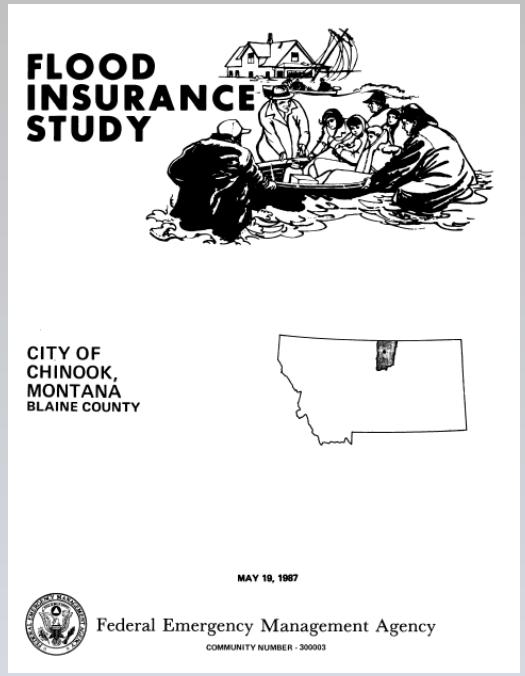
Redrock Coulee Bridge Replacement



Lohman – East & West
Redrock Coulee Bridge Replacement

- PROJECT CHALLENGE #1 – DETAILED FLOODPLAIN INVESTIGATION
  - Multiple Studies on the Floodplain
    - Original FIS – 1987
    - LOMR – 1993 Chinook Airport Expansion
    - Updated FIS - 2006



- INITIAL ASSUMPTIONS BASED ON INVESTIGATION
  - 1987 FIS
    - Modeled in HEC-2
    - Hydrology – Regional Frequency
    - Basic Flow Spilt Analysis Completed
    - East and West Overflow Bridges NOT Modeled
    - No Return Flow From the Overflow Bridges
    - Milk River and Redrock Coulee Modeled Independently

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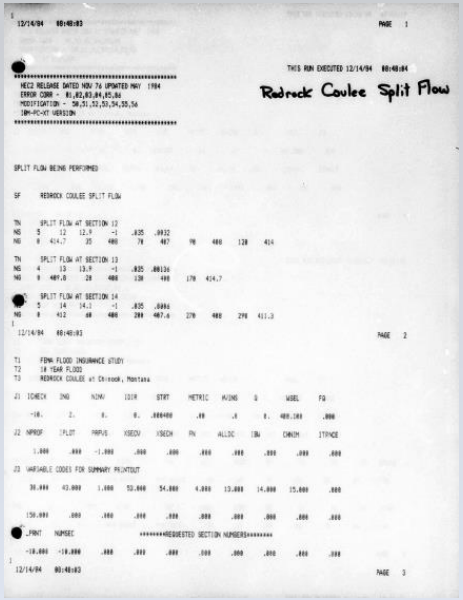
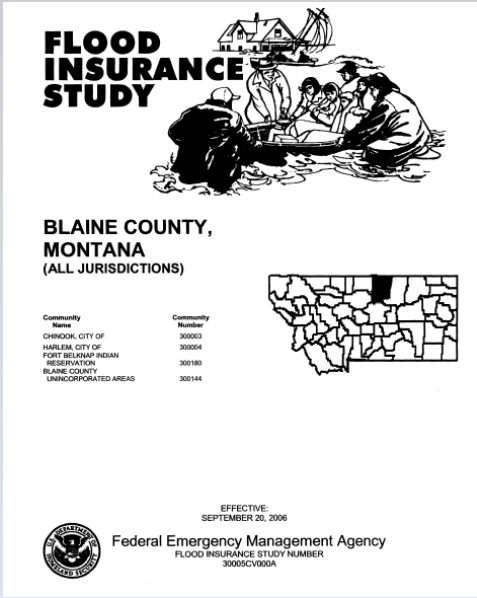
Redrock Coulee Bridge Replacement

- INITIAL ASSUMPTIONS BASED ON INVESTIGATION (CONTINUED)
  - **1993 LOMR**
    - Modeled in HEC-2
    - Channel was Lengthened Due to Runway Extension
    - Hydrology and Flow Splits Adopted from 1987 FIS
    - Additional XS's Added to Redrock Coulee Model
  - **2006 FIS**
    - Incorporated the changes from the 1993 LOMR





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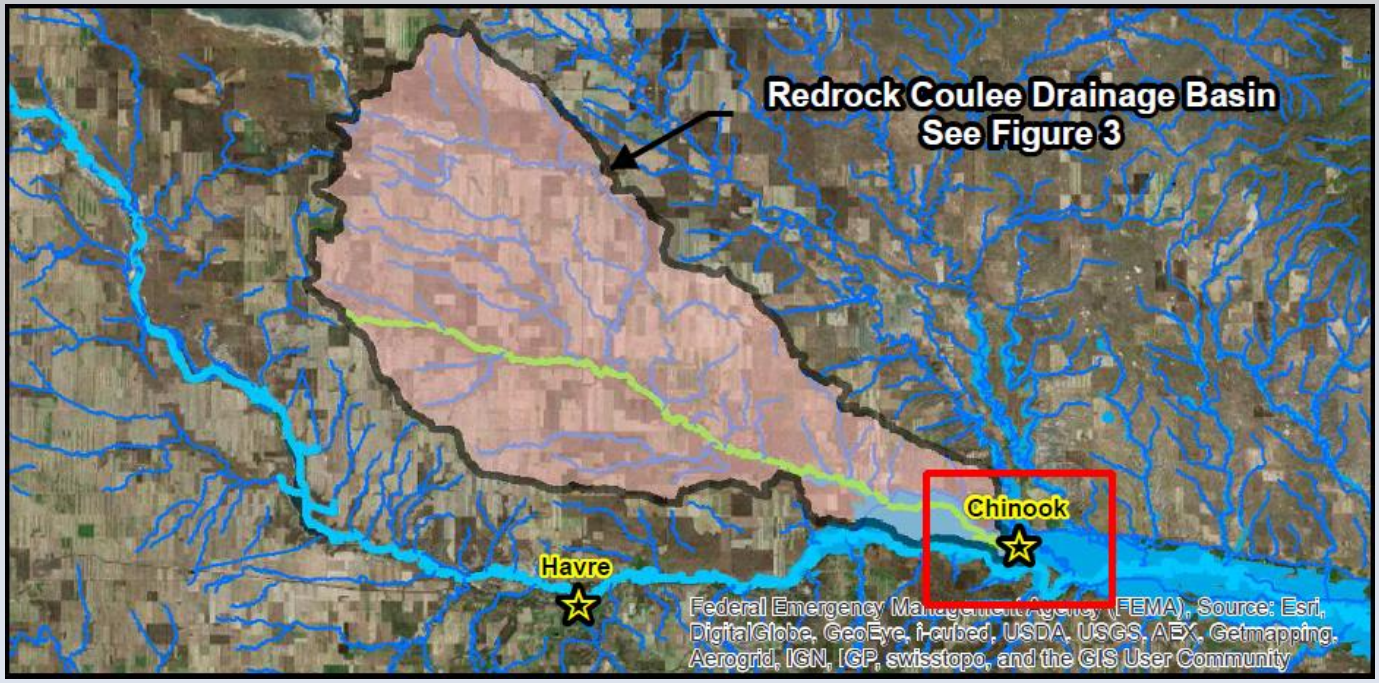
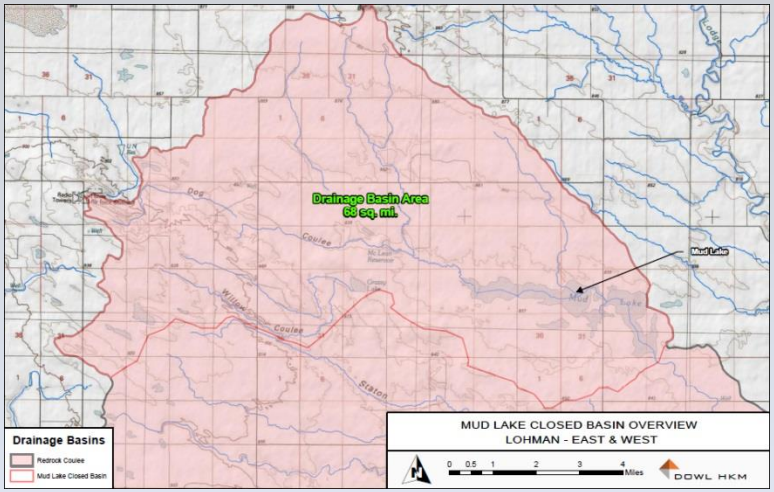
Redrock Coulee Bridge Replacement

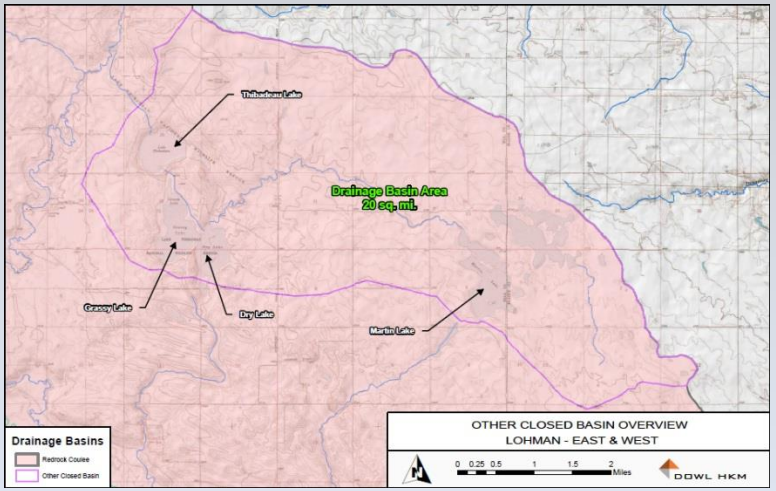
- PROJECT CHALLENGE #2 – HYDROLOGY
  - An Independent Evaluation was Completed
    - 5 Separate Hydrologic Analysis Completed
    - Used to verify FIS Hydrology
  - Drainage Basin Area = 363 sq. mi.
  - FIS Drainage Basin Area = 265 sq. mi.



Lohman – East & West
Redrock Coulee Bridge Replacement

- PROJECT CHALLENGE #2 – HYDROLOGY
  - Investigation into the Previous Studies
    - Very Limited Documentation
    - 1987 FIS States there are closed basins for a neighboring stream
    - Assumption – Potential for Closed Basins
  - Further Review of Aerial Imagery Showed Closed Basins
    - Drainage Basin Excluding Closed Basins = <u>275 sq. mi.</u>
    - FIS Drainage Basin Area = <u>265 sq. mi.</u>
  - Conclusion
    - Calculated Flows Were Within 10% of the Reported FIS Flows





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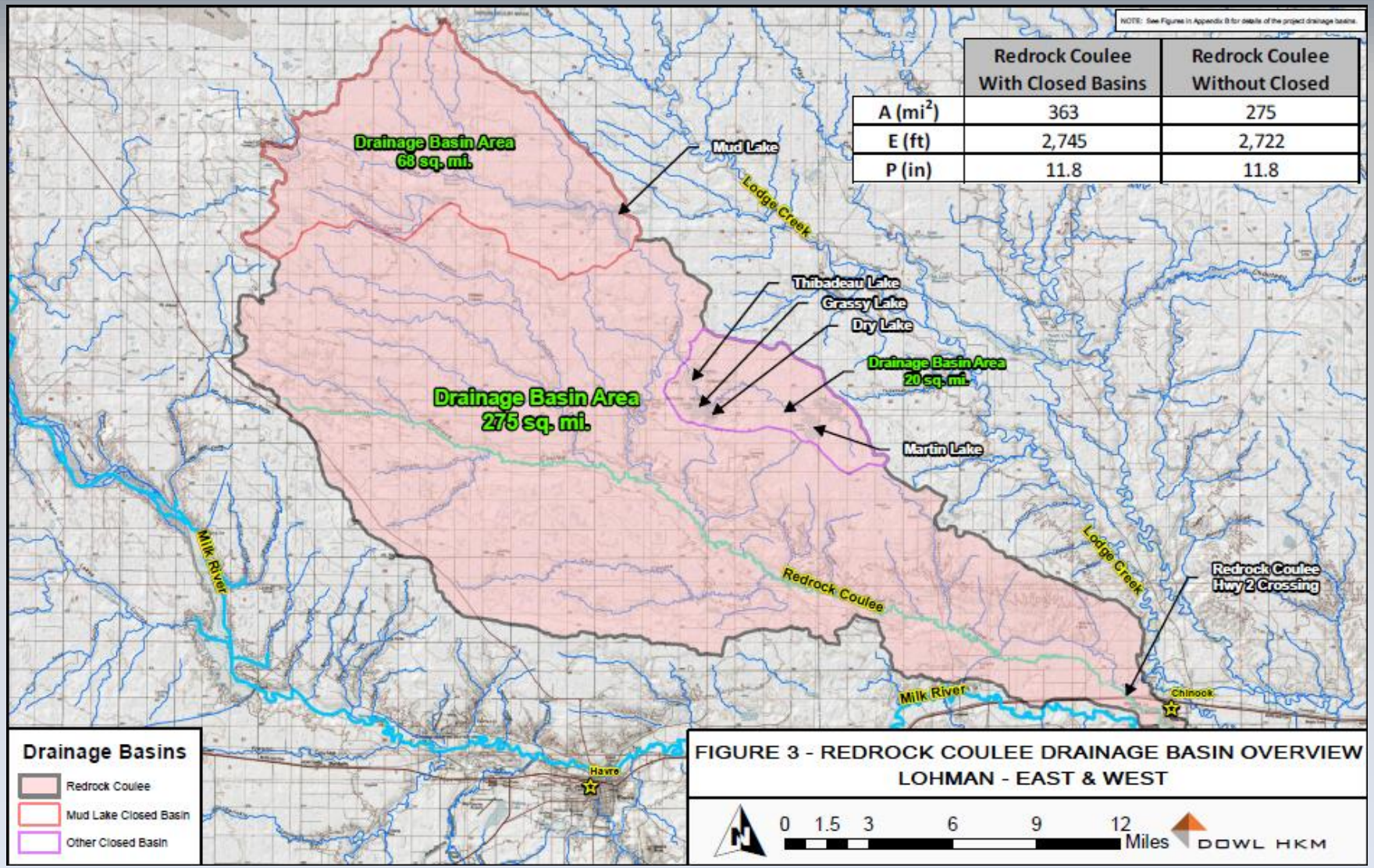
Redrock Coulee Bridge Replacement



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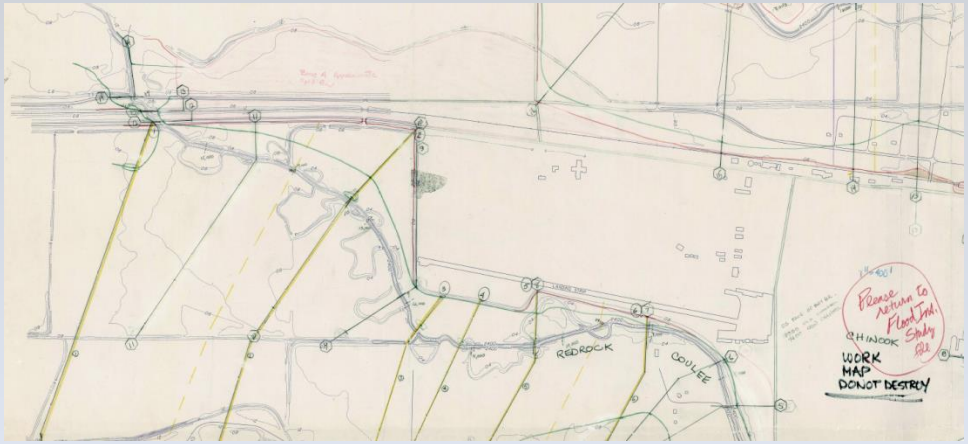
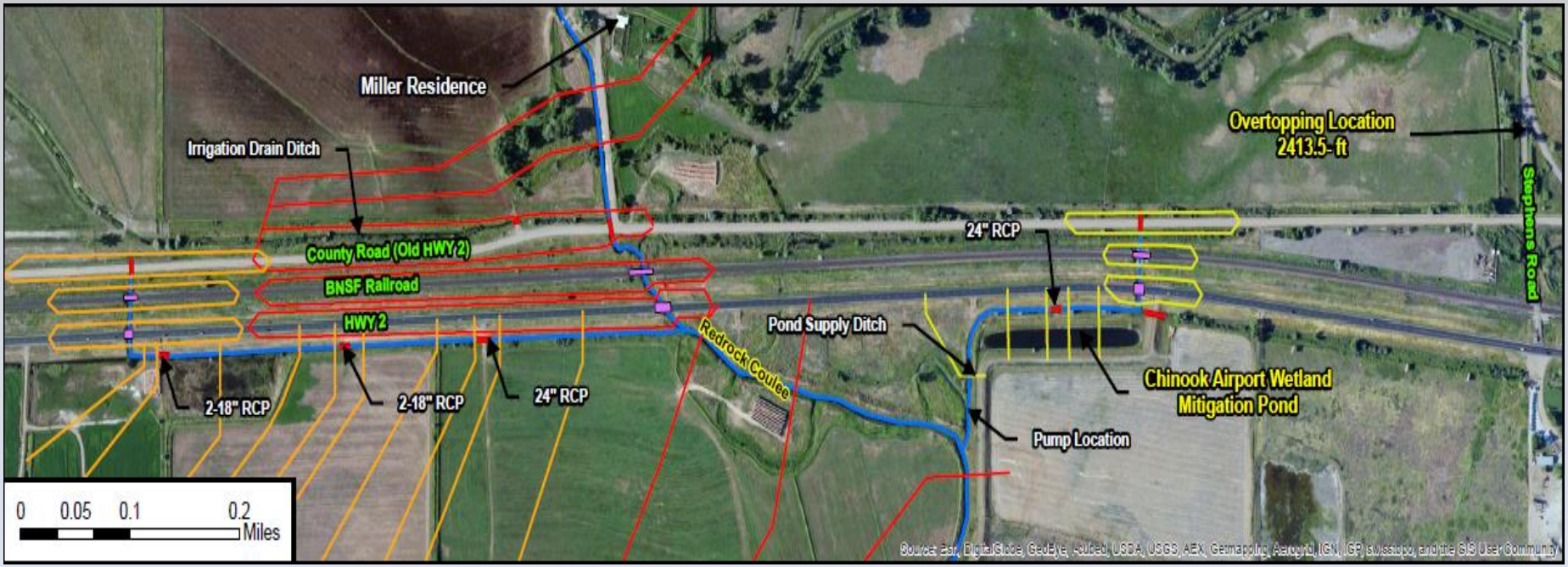
Redrock Coulee Bridge Replacement

- PROJECT CHALLENGE #3 – STREAM/REACH LENGTHS
  - Duplicate Effective Model
    - Data from the 1993 LOMR was used
      - 2 Cross Sections were Added to the 1987 FIS Model
      - But the River Stationing was not updated.
  - Corrected Effective Model
    - Using Updated Aerial Imagery and GIS
      - The River Stationing was Updated
      - Additional Cross Sections Were Added



Lohman – East & West
Redrock Coulee Bridge Replacement

- PROJECT CHALLENGE #4 – FLOW SPLITS
  - Flow Splits From the 1987 FIS Were Adopted in the 1993 LOMR
    - Problems:
      - Calculated using best technology at the time
        - Manning's Equation
      - Flow DID NOT Return to the Model
      - Limited Documentation = No Explanation Why???

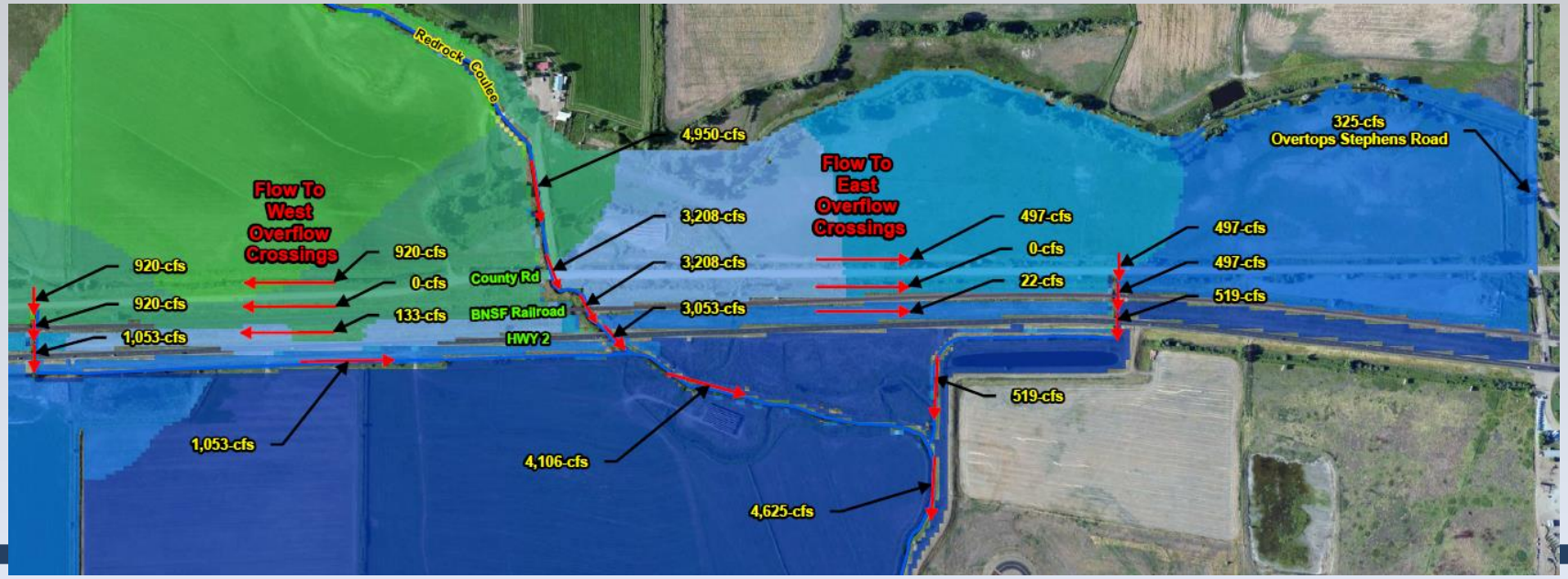


Lohman – East & West
Redrock Coulee Bridge Replacement

- PROJECT CHALLENGE #4 – FLOW SPLITS
  - Challenge – How to Better Model the Complex Flow
  - Solution – Two-Dimensional Hydraulic Model
    - FLO-2D PRO was used
    - Grid Based Model – 20 ft Cell Size
    - DEM Data
      - Photogrammetry
      - Topographic Survey
      - 5 Meter IfSAR Data
    - Channels Were Built Into the Model
    - Bridges and Culverts were Modeled as Hydraulic Structures

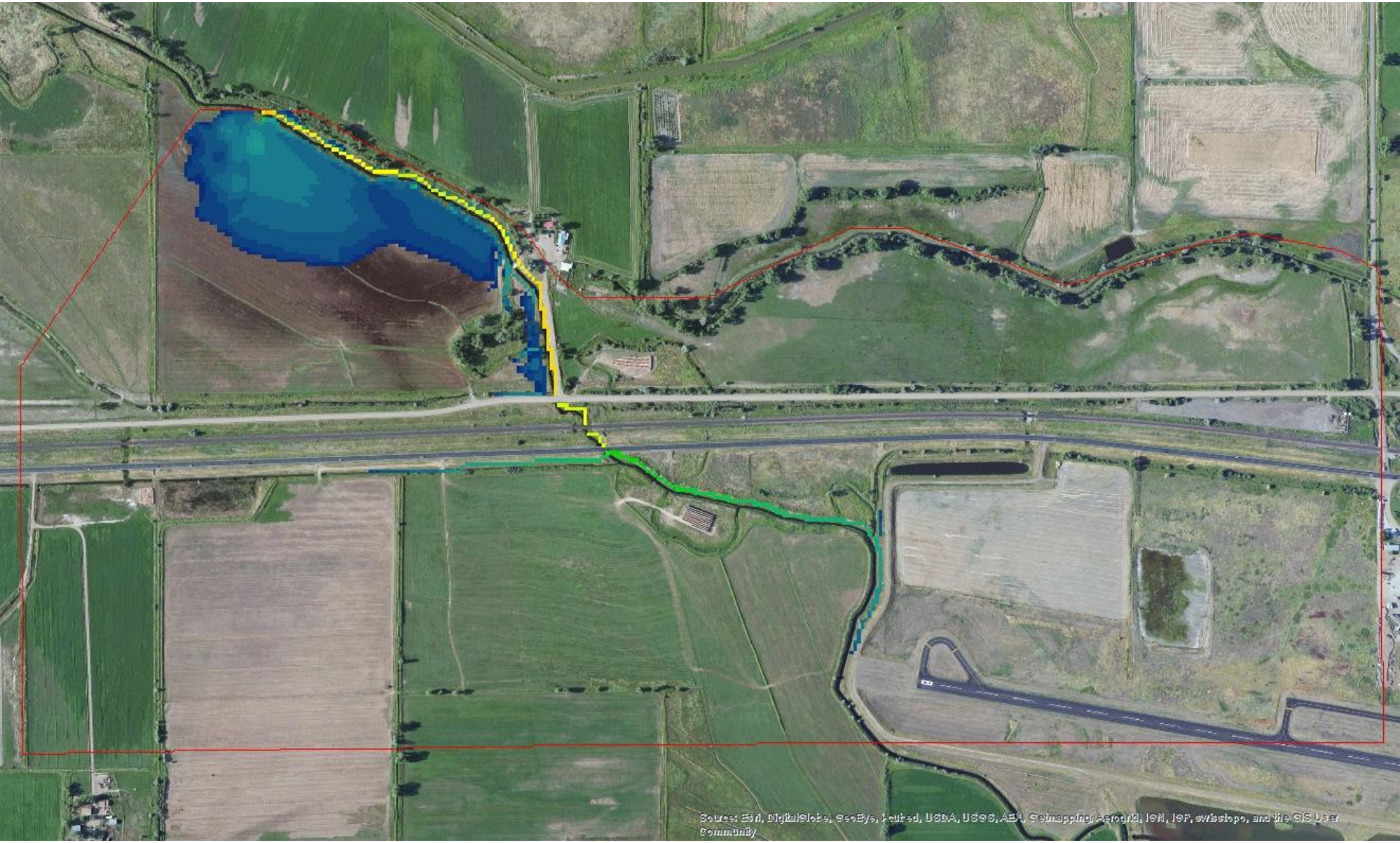
Lohman – East & West
Redrock Coulee Bridge Replacement

- PROJECT CHALLENGE #4 – FLOW SPLITS
  - Findings:
    - Two-Dimensional Hydraulic Model Results
      - Flow Does Return to the Main Channel
      - Some Flow Does Leave the System
    - Implications:
      - Returning Flow = Greater Backwater Influences on All Crossings
      - 100-yr FIS Flow Downstream of Main Bridge = 1,900 cfs
      - 100-yr 2-D Flow Downstream of Main Bridge = 4,106 cfs



100-Year Model – Simulation Time = 0.2 hrs

100-Year Model – Simulation Time = 0.4 hrs



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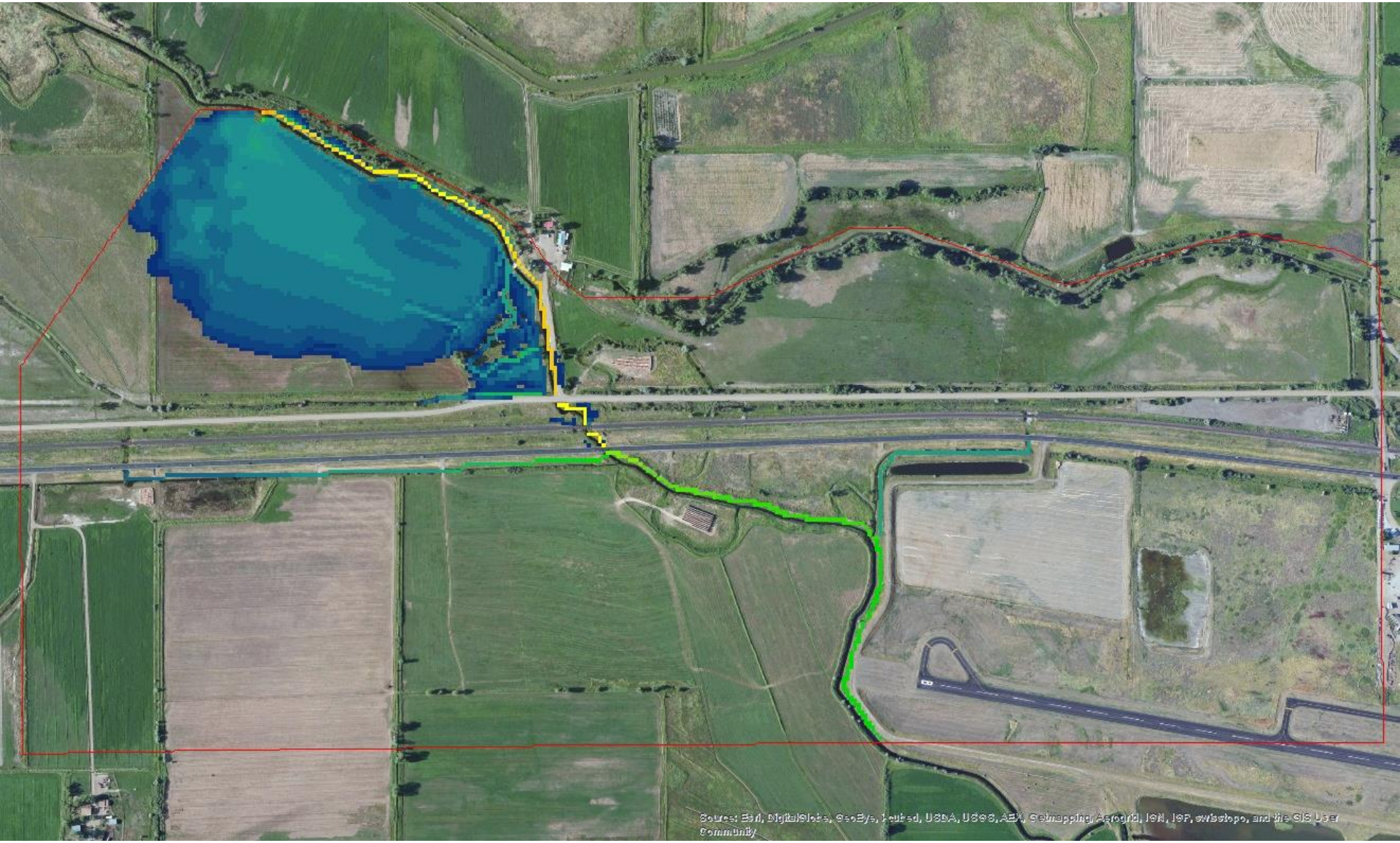

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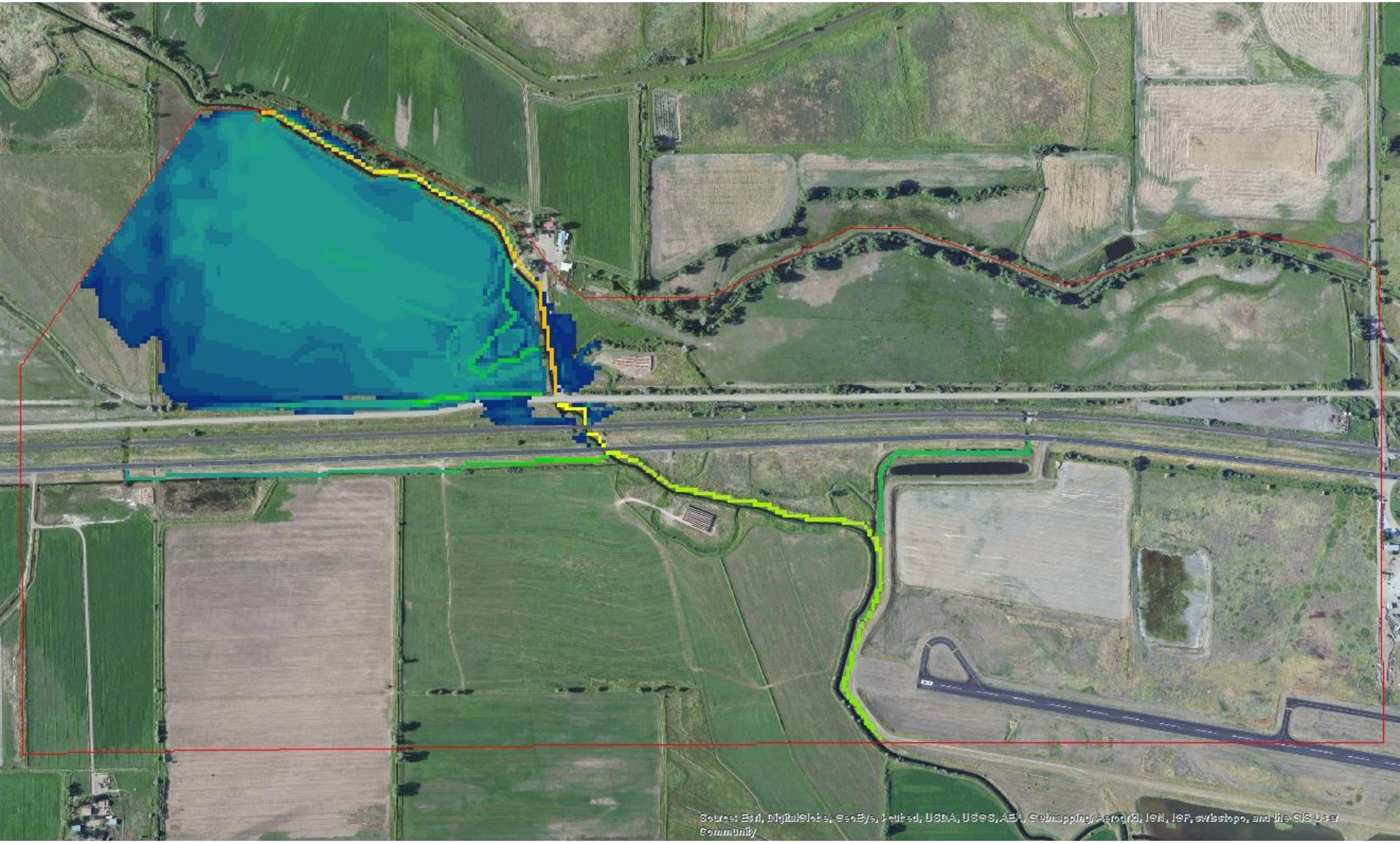
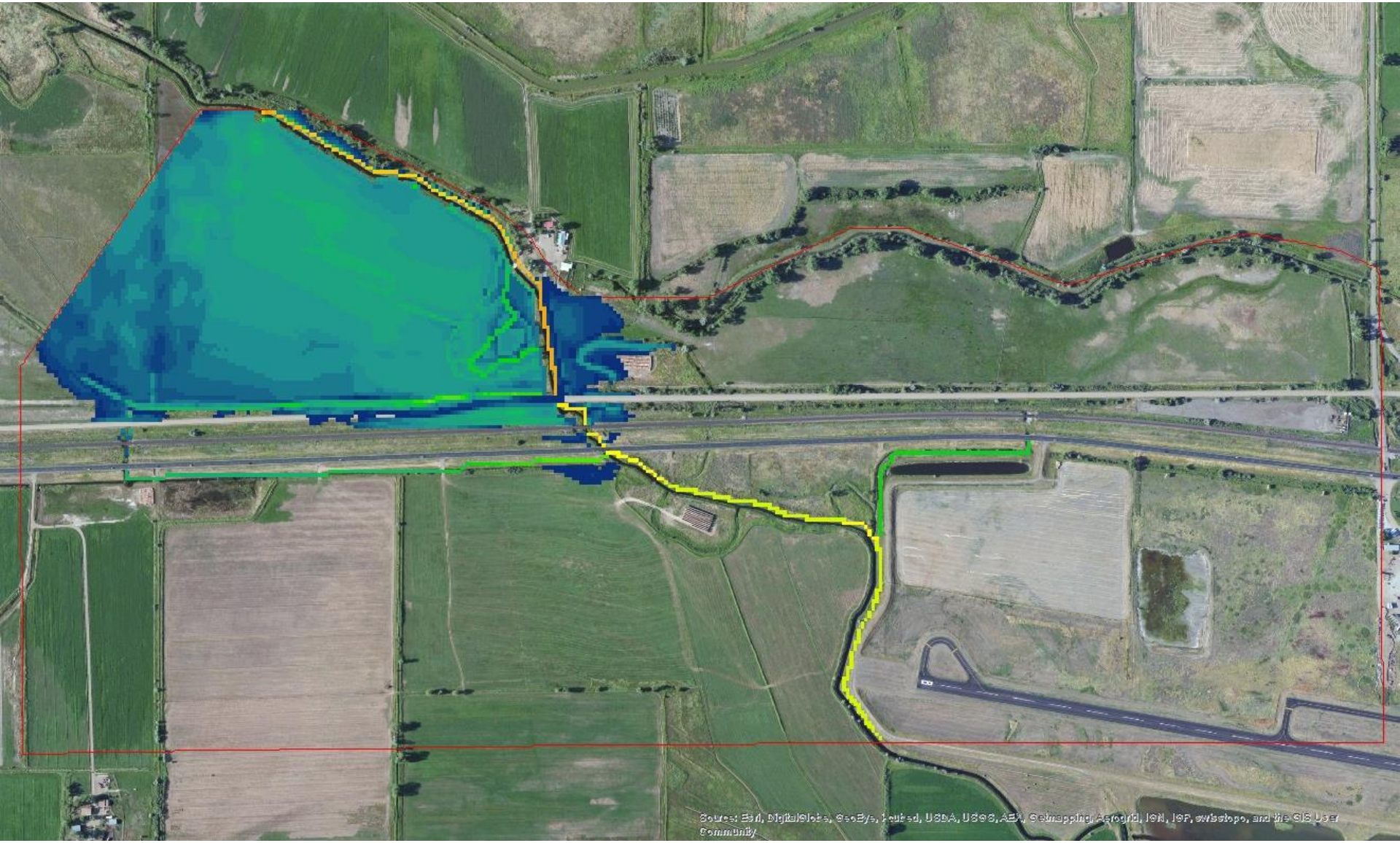
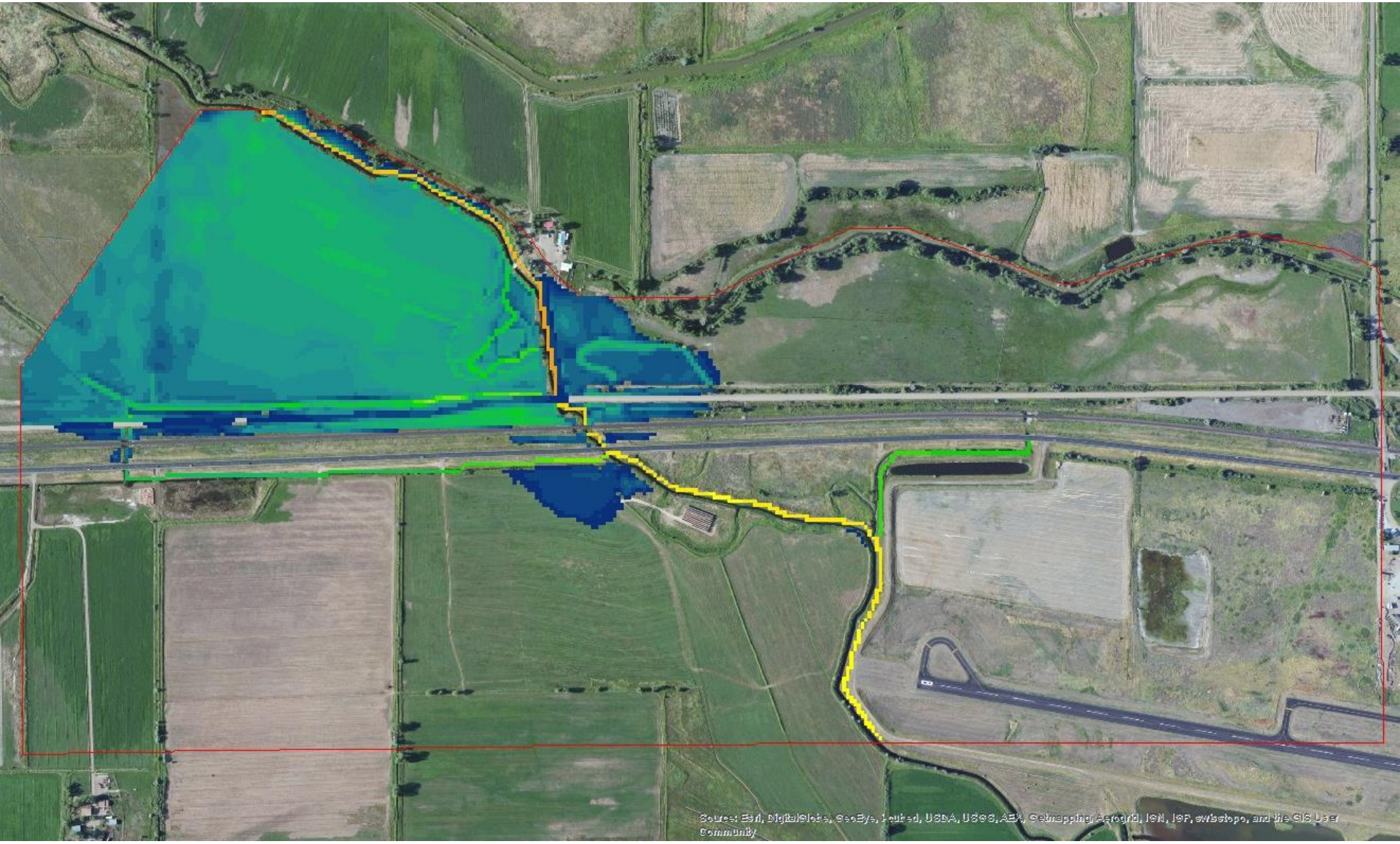


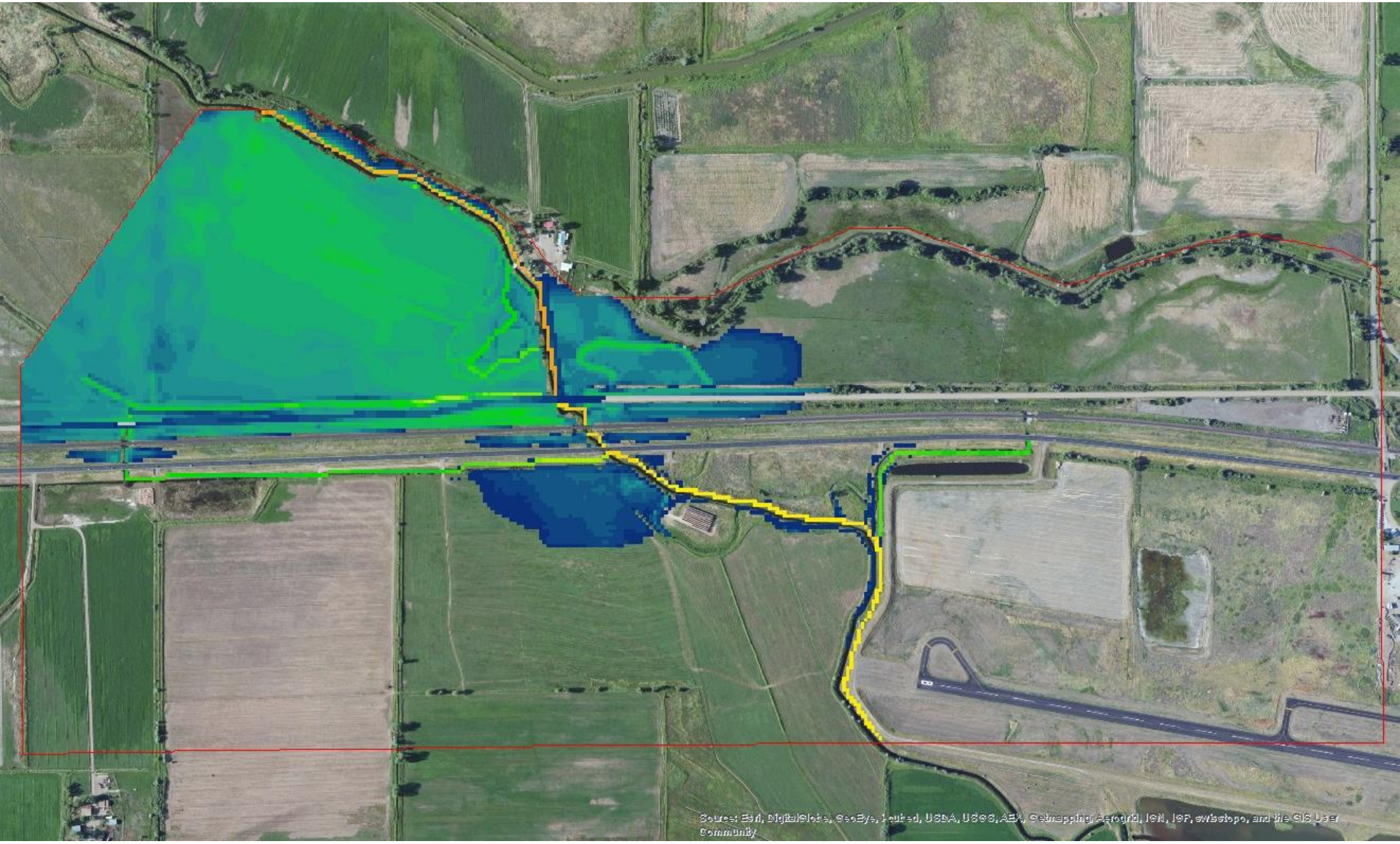
100-Year Model – Simulation Time = 1.0 hrs



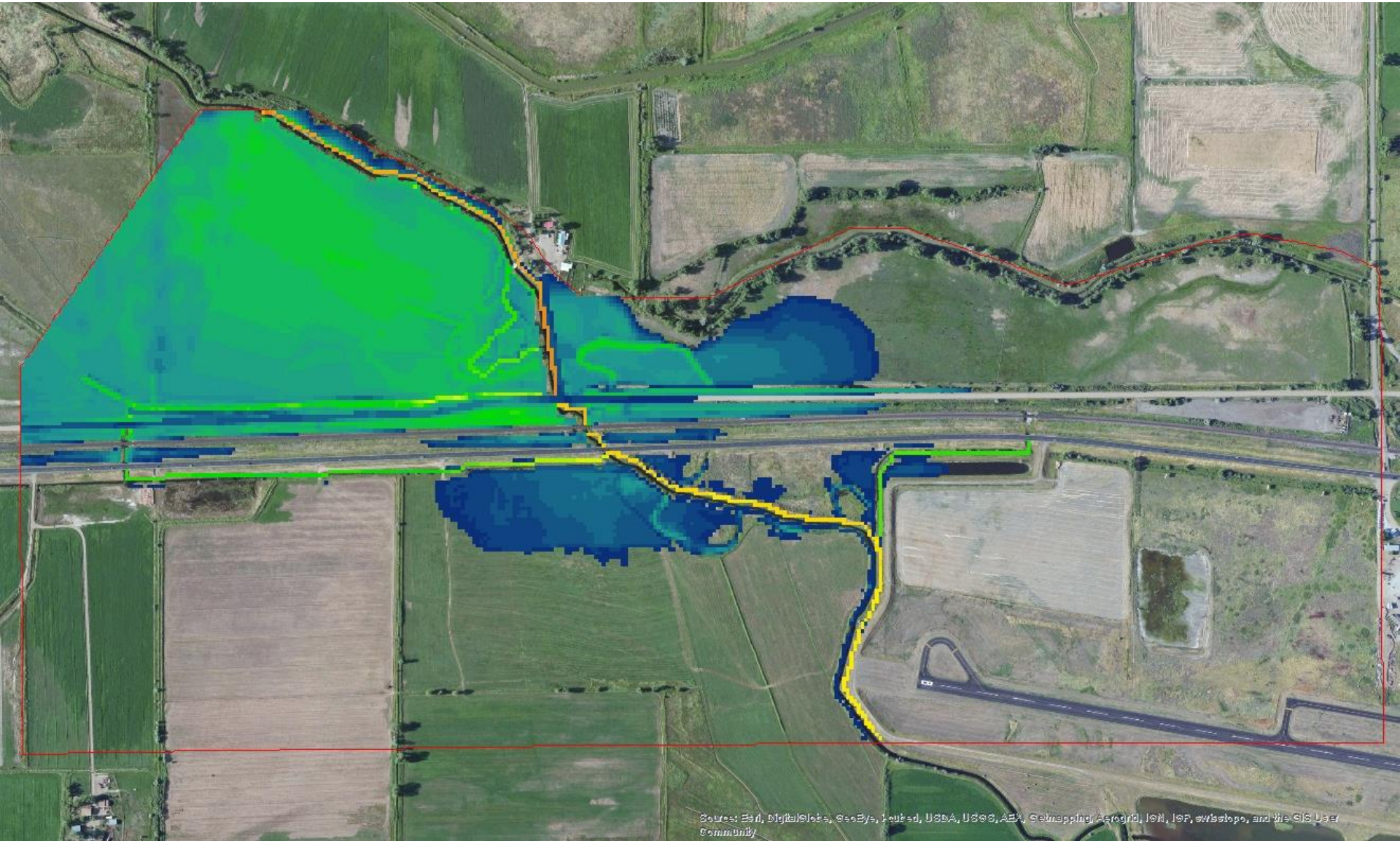
100-Year Model – Simulation Time = 1.2 hrs



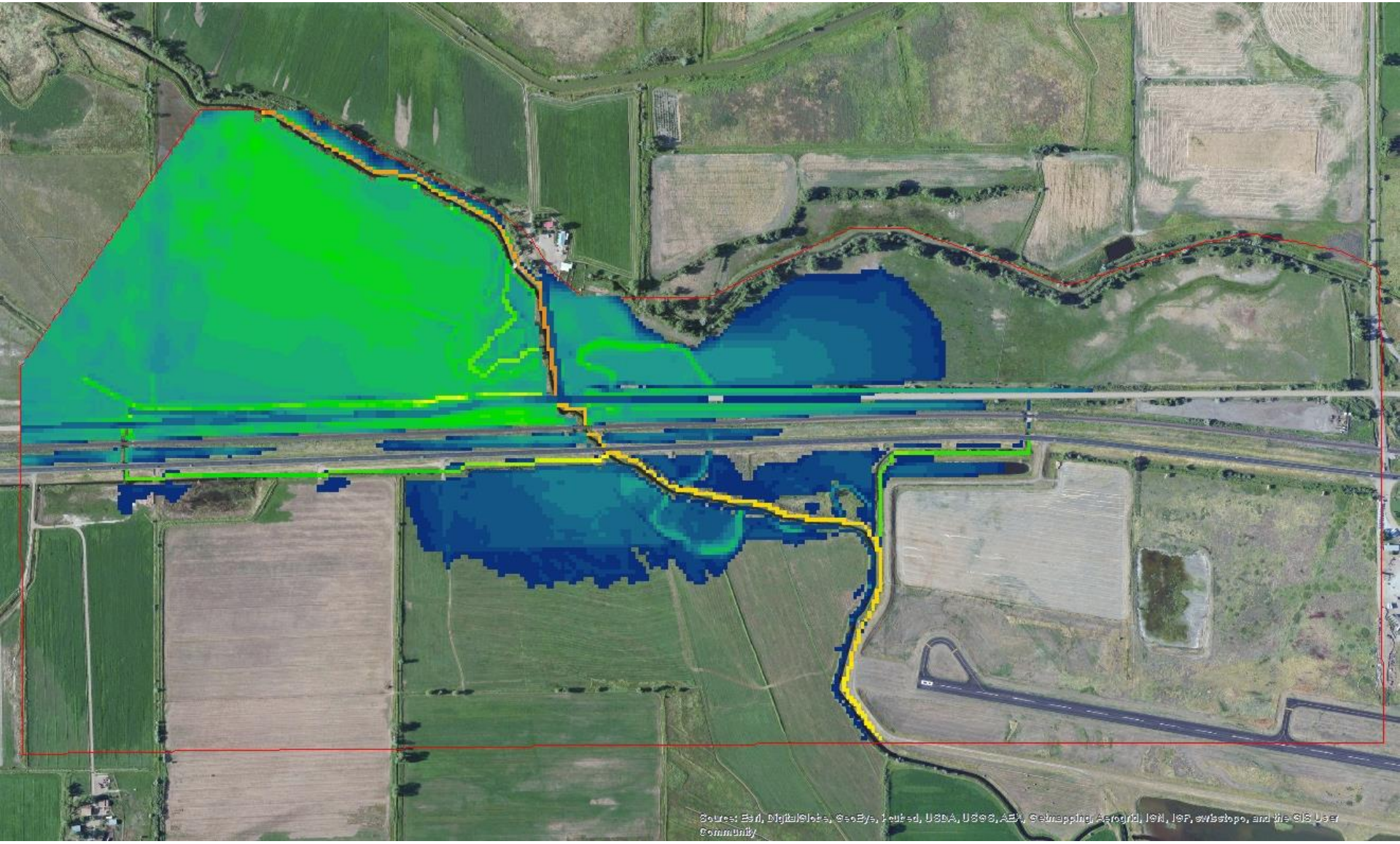
100-Year Model – Simulation Time = 1.4 hrs



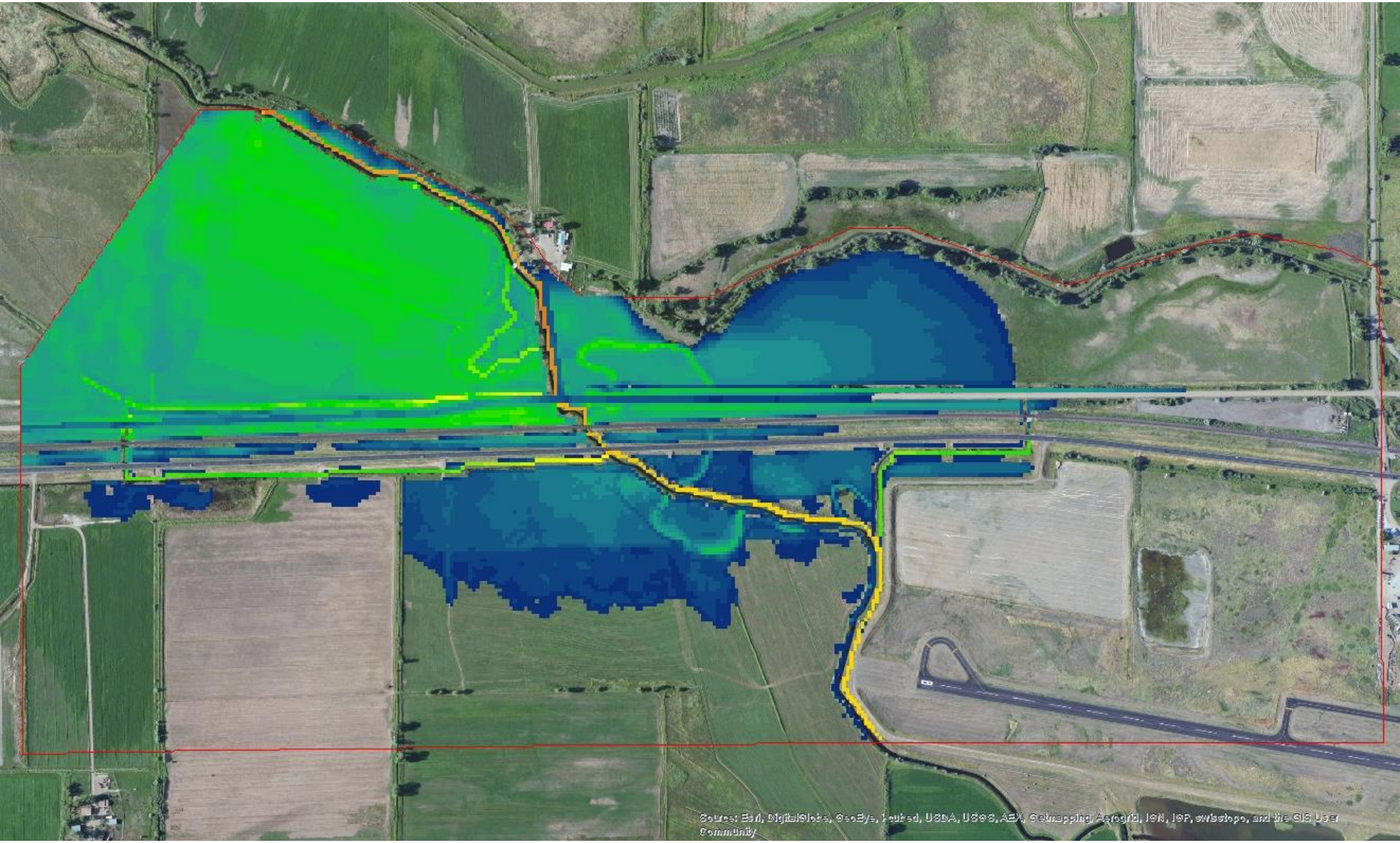
100-Year Model – Simulation Time = 1.6 hrs



100-Year Model – Simulation Time = 1.8 hrs



100-Year Model – Simulation Time = 2.0 hrs



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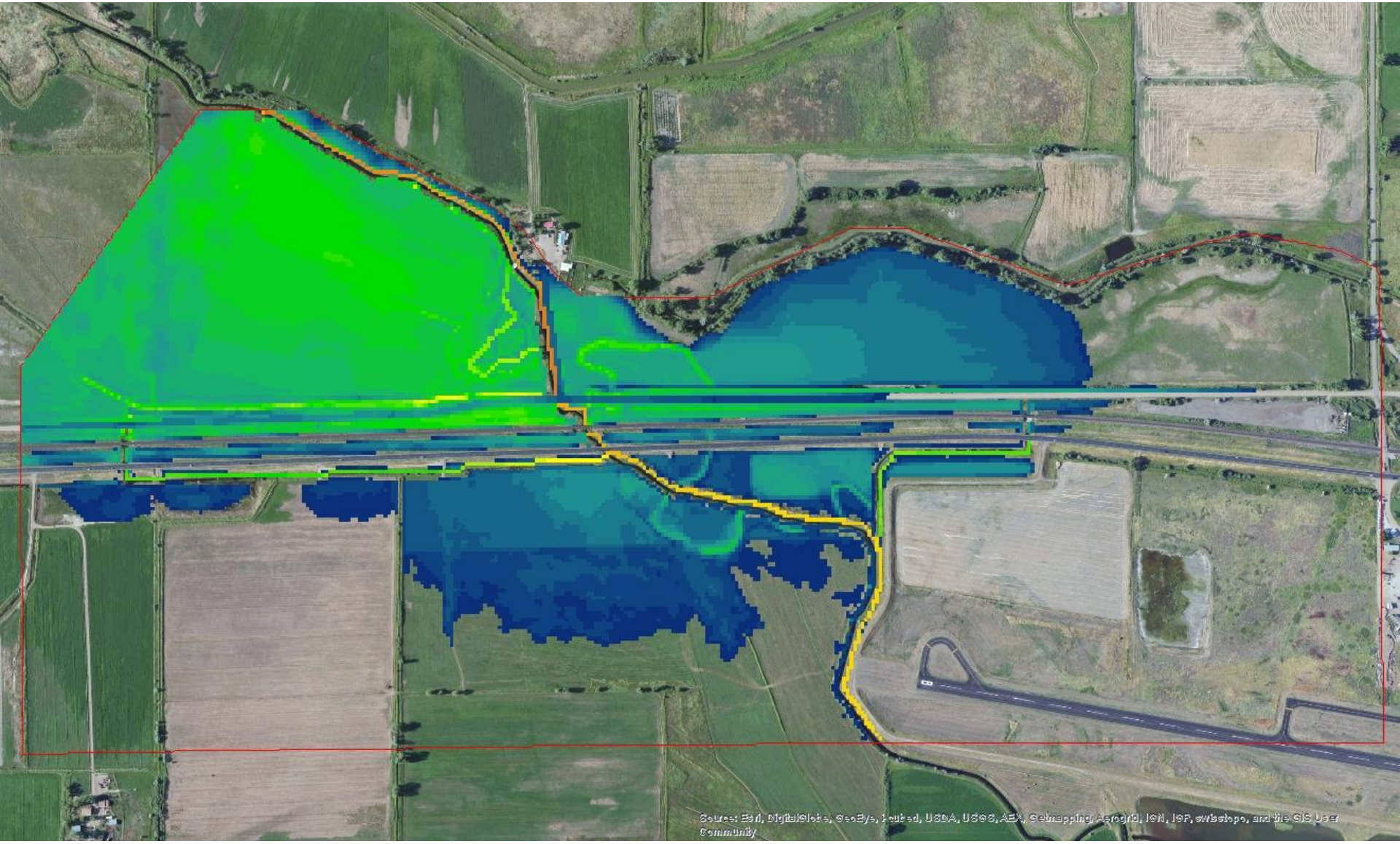
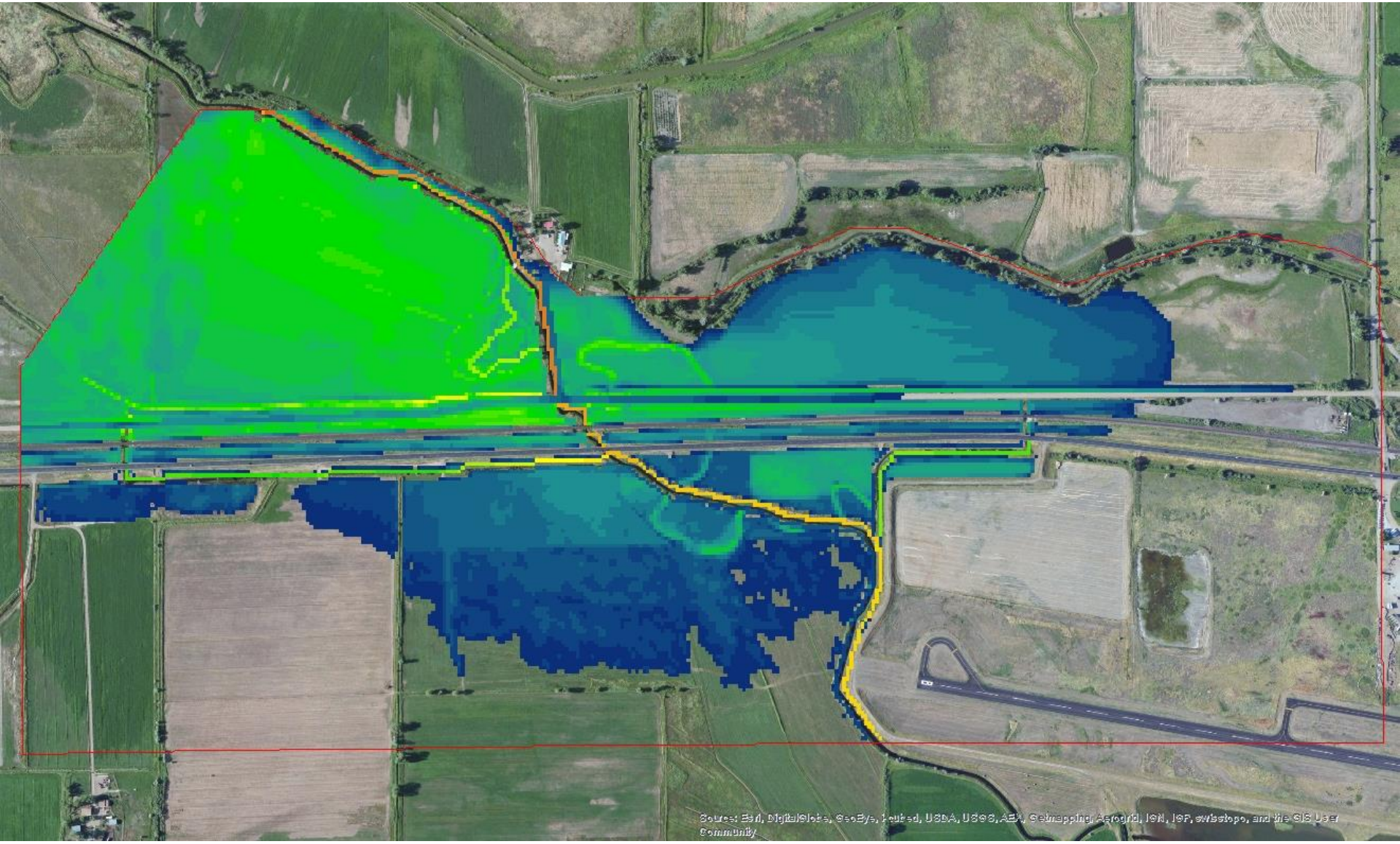
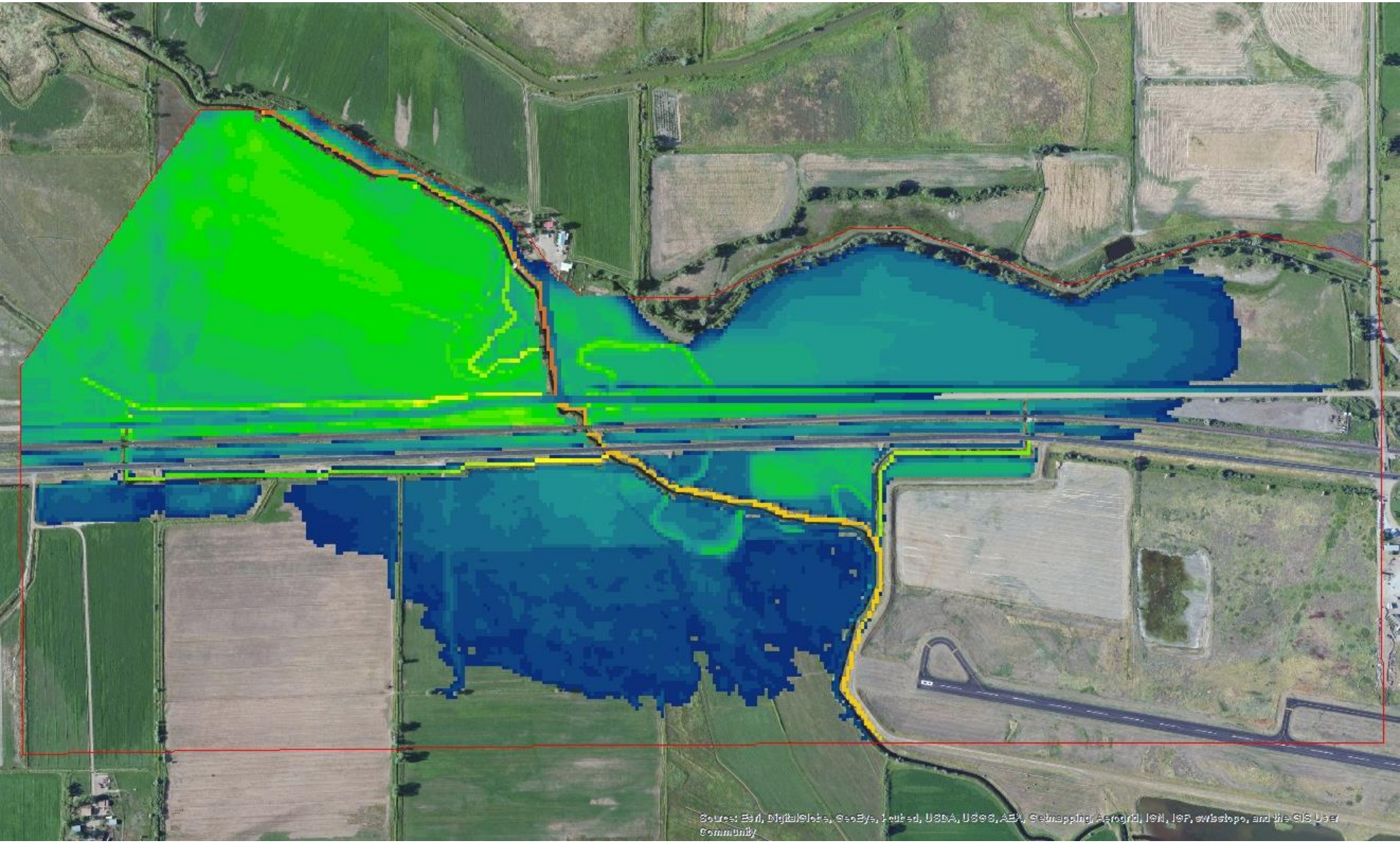


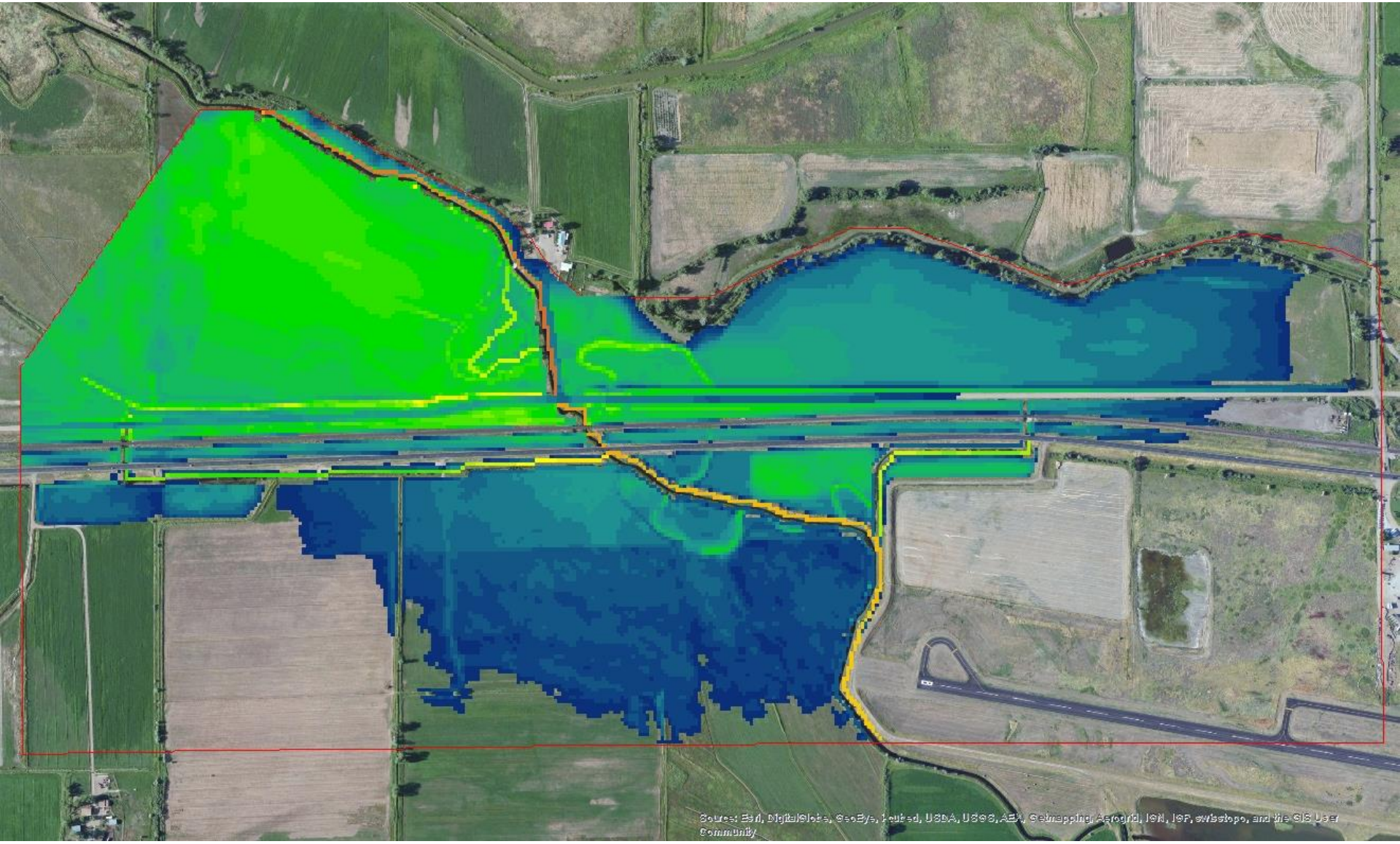
100-Year Model – Simulation Time = 2.4 hrs



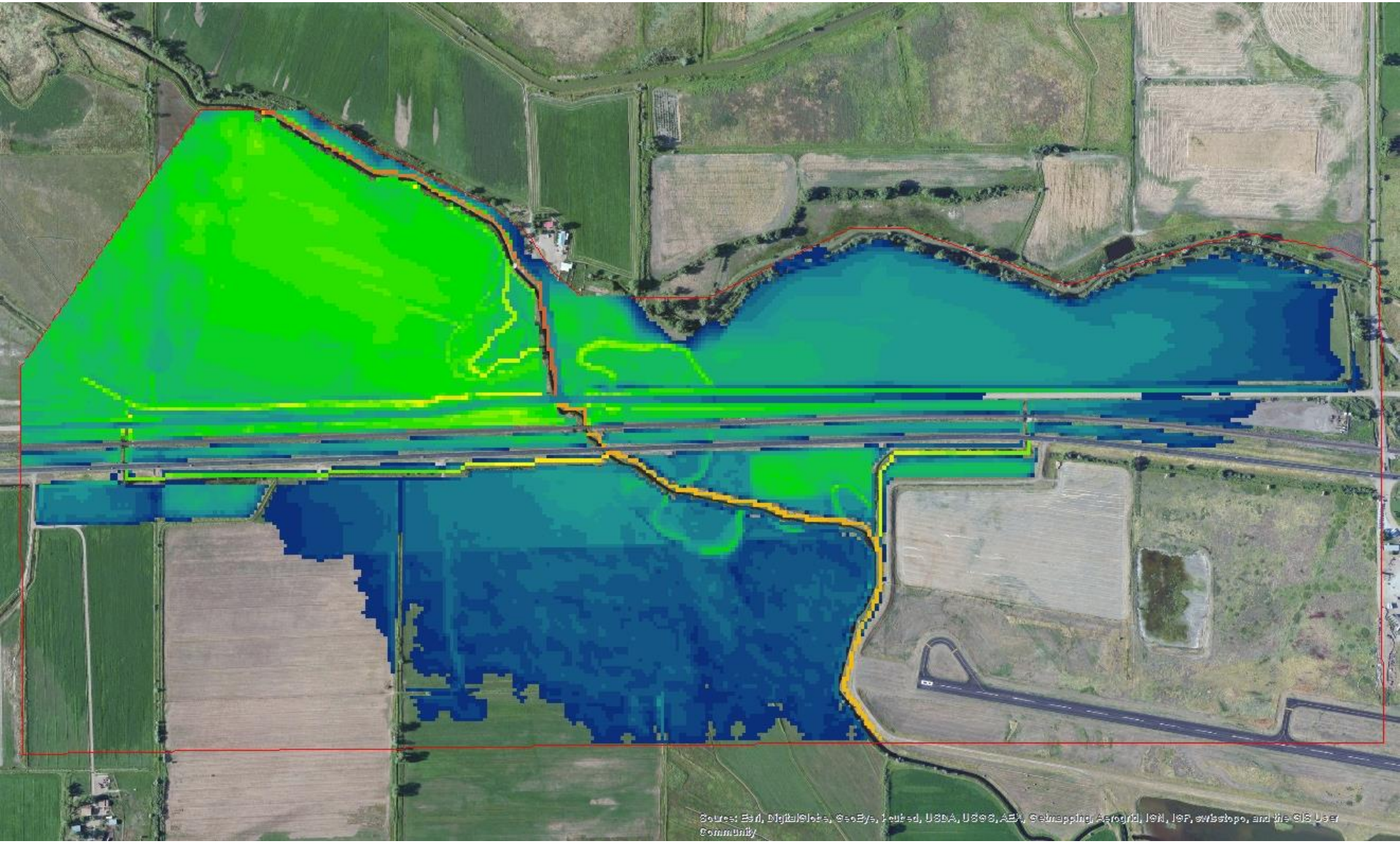
100-Year Model – Simulation Time = 2.6 hrs



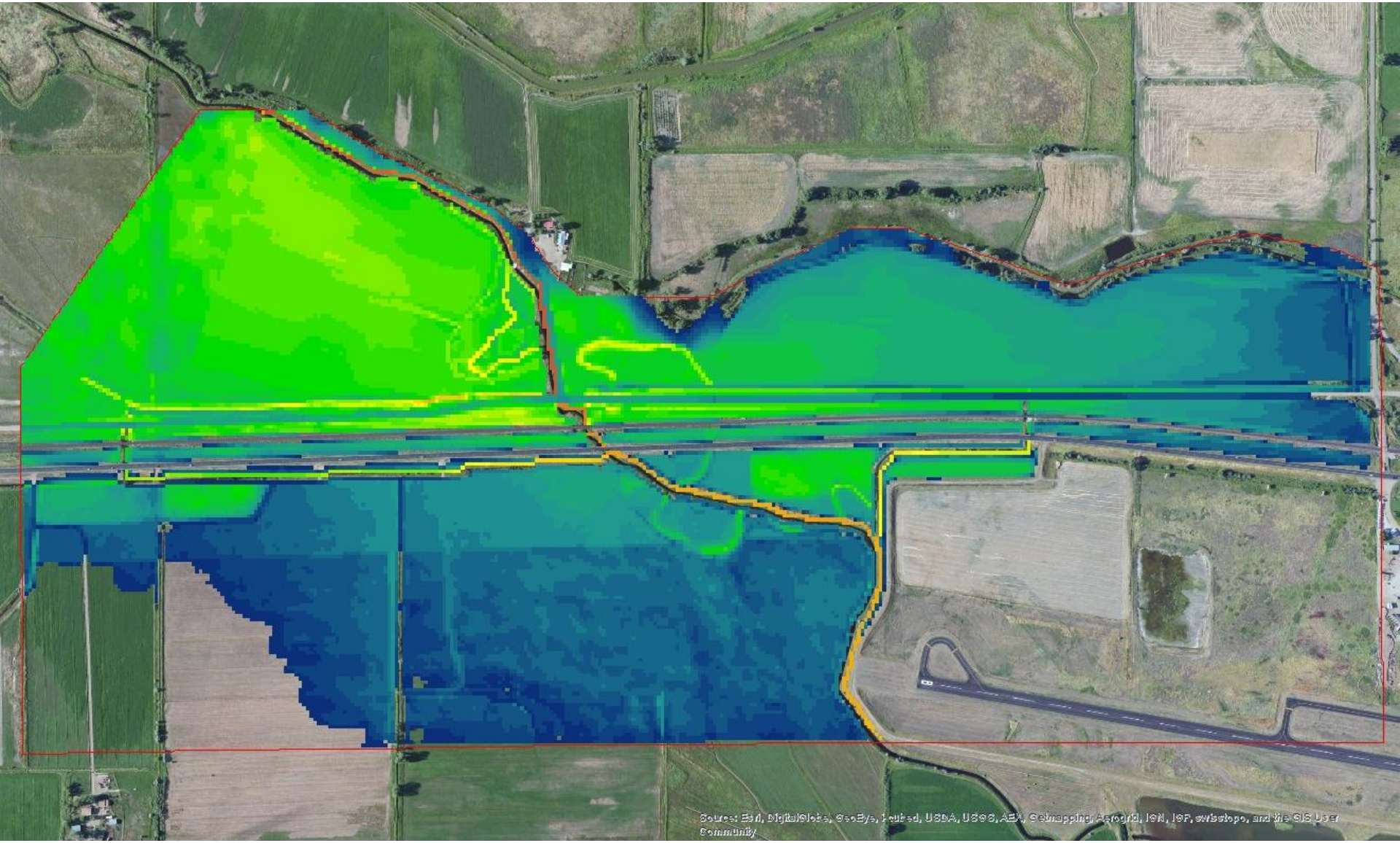
100-Year Model – Simulation Time = 2.8 hrs



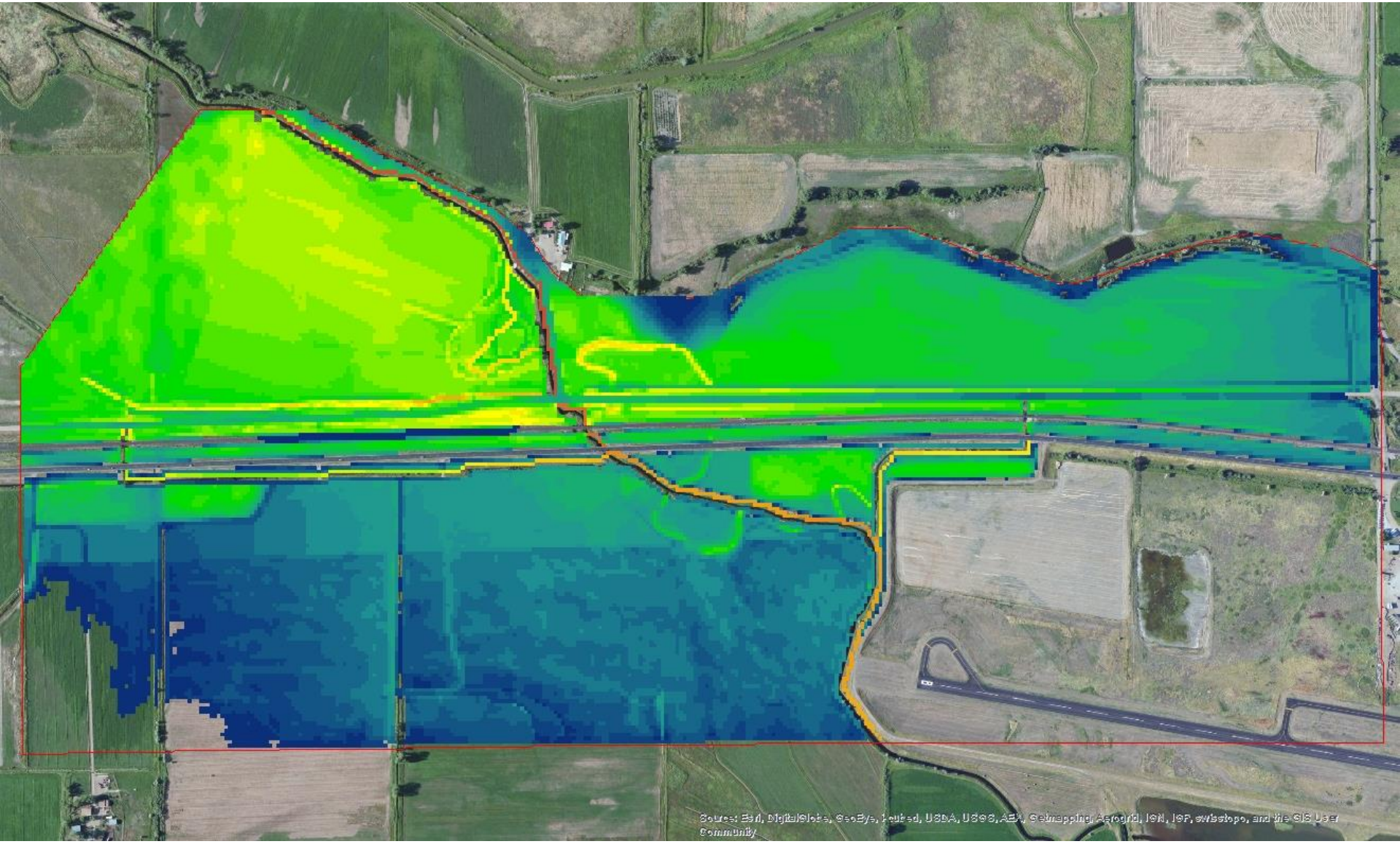
100-Year Model – Simulation Time = 3.0 hrs



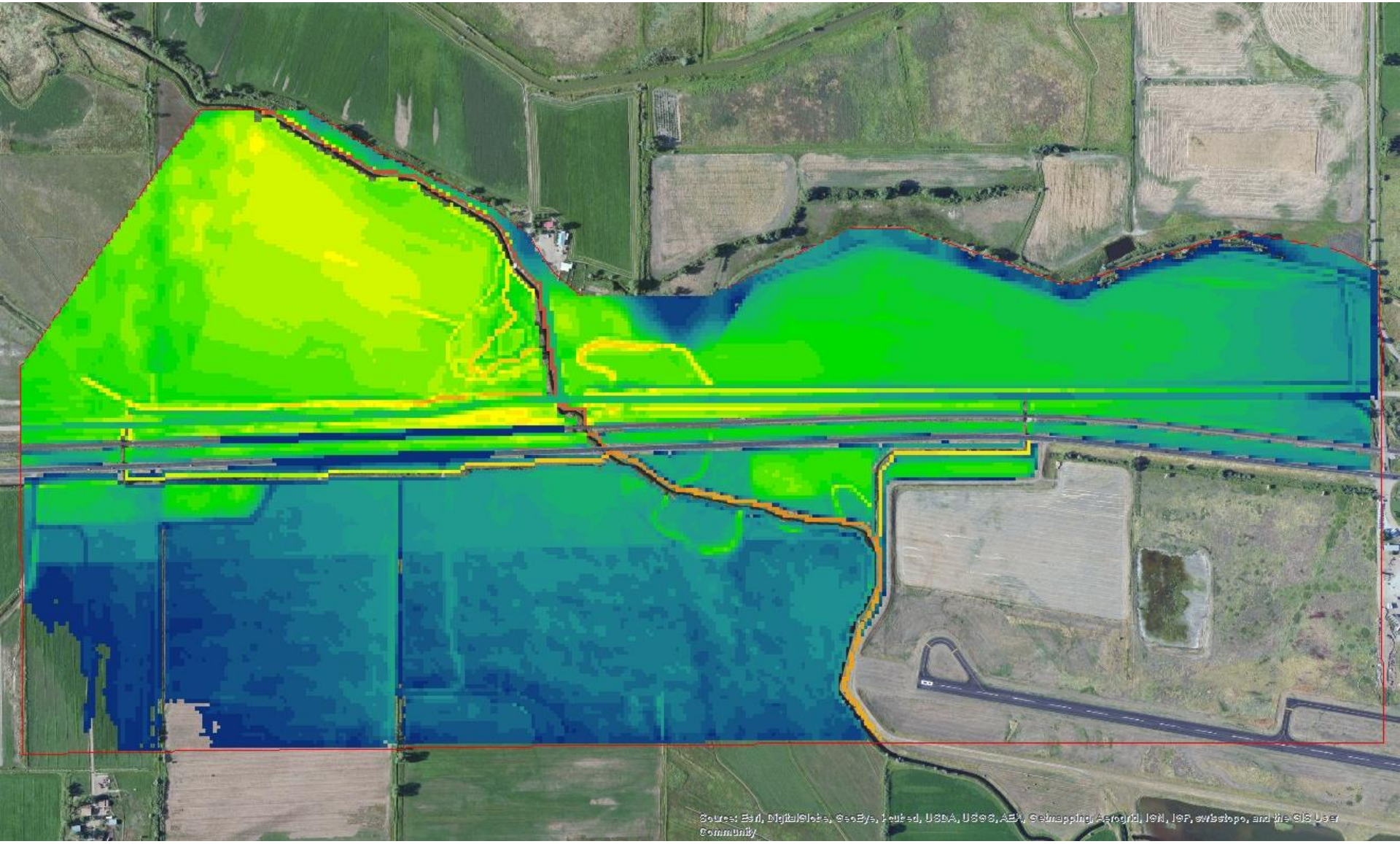
100-Year Model – Simulation Time = 4.0 hrs



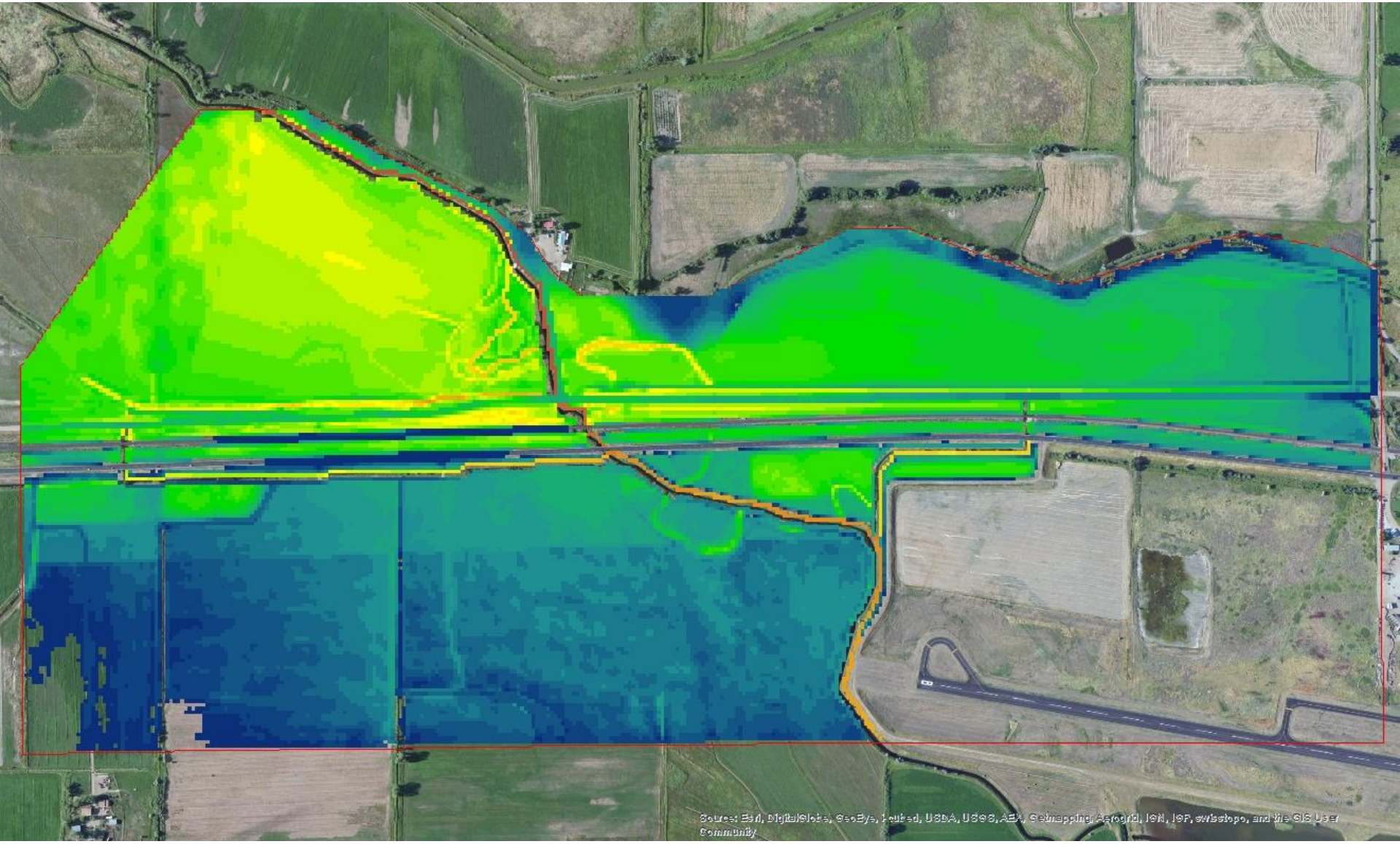
100-Year Model – Simulation Time = 6.0 hrs



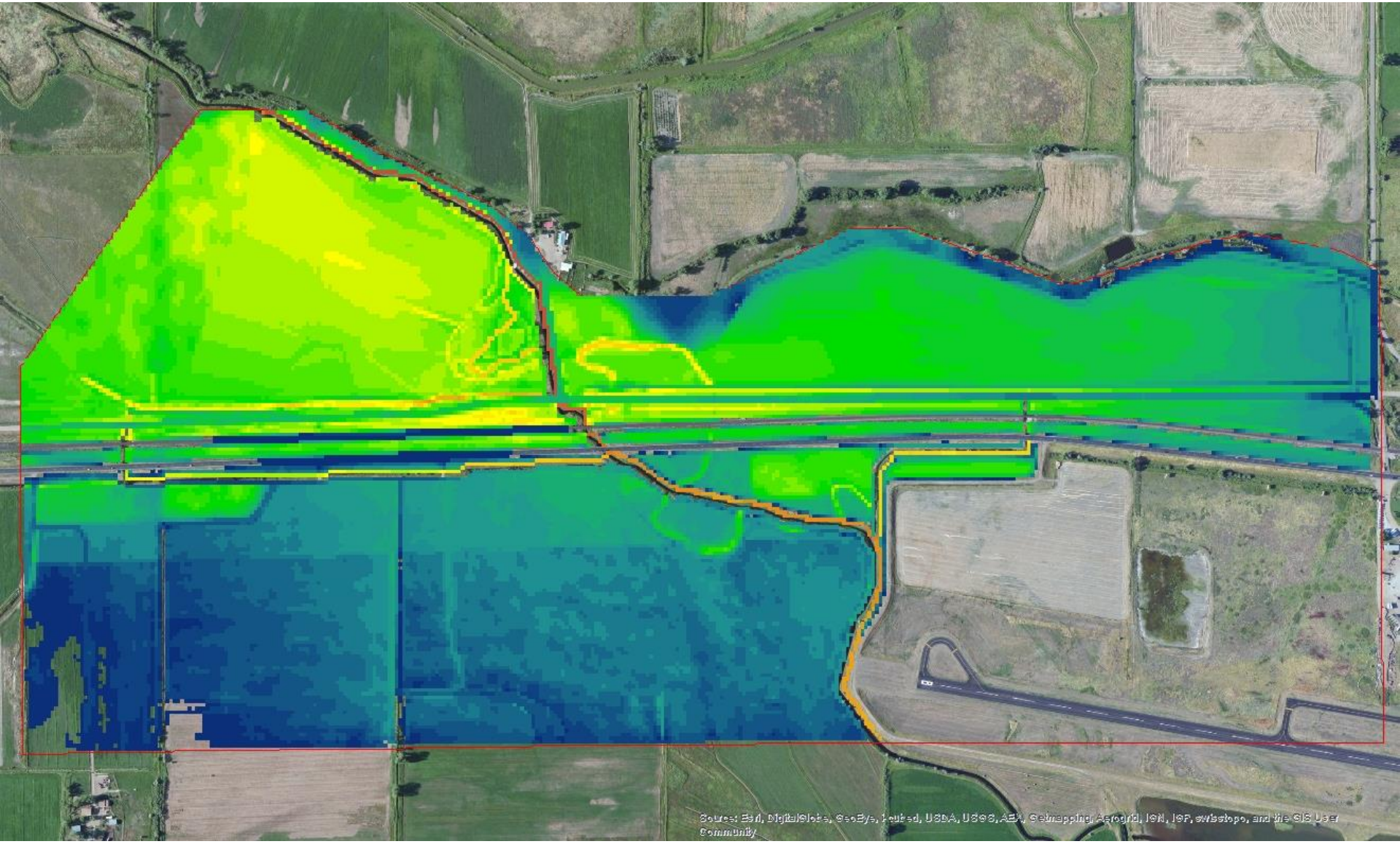
100-Year Model – Simulation Time = 8.0 hrs



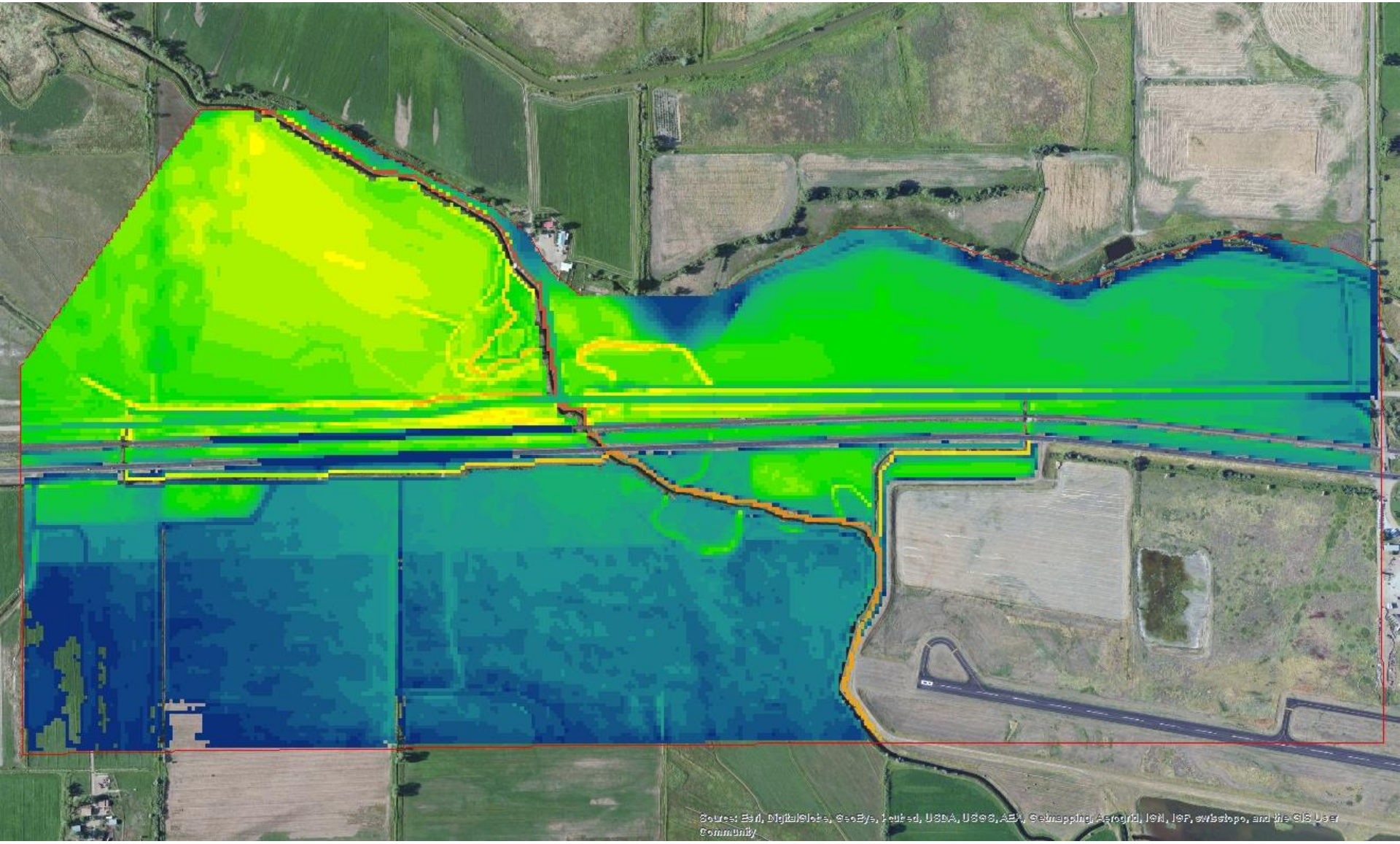
100-Year Model – Simulation Time = 10.0 hrs



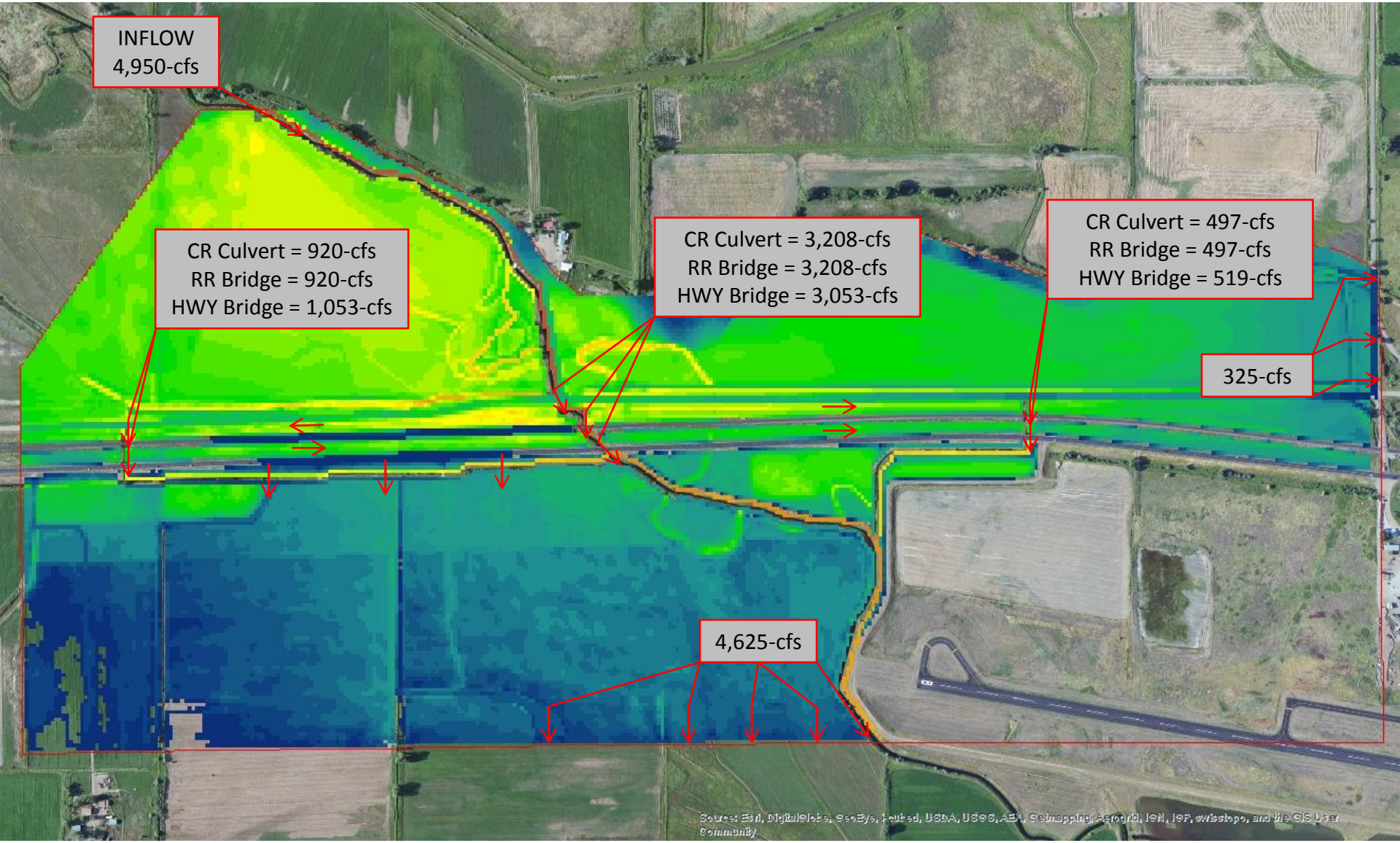
100-Year Model – Simulation Time = 14.0 hrs



100-Year Model – Simulation Time = 20.0 hrs

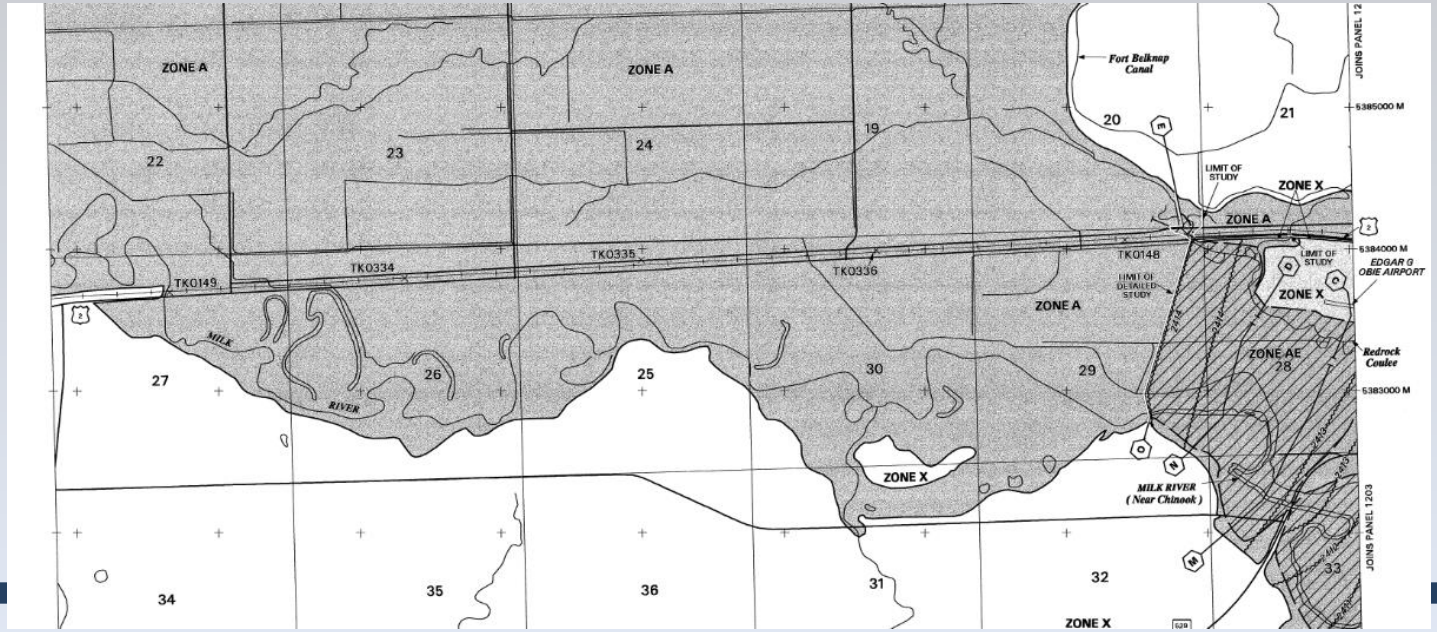


100-Year Model – Simulation Time = 20.0 hrs

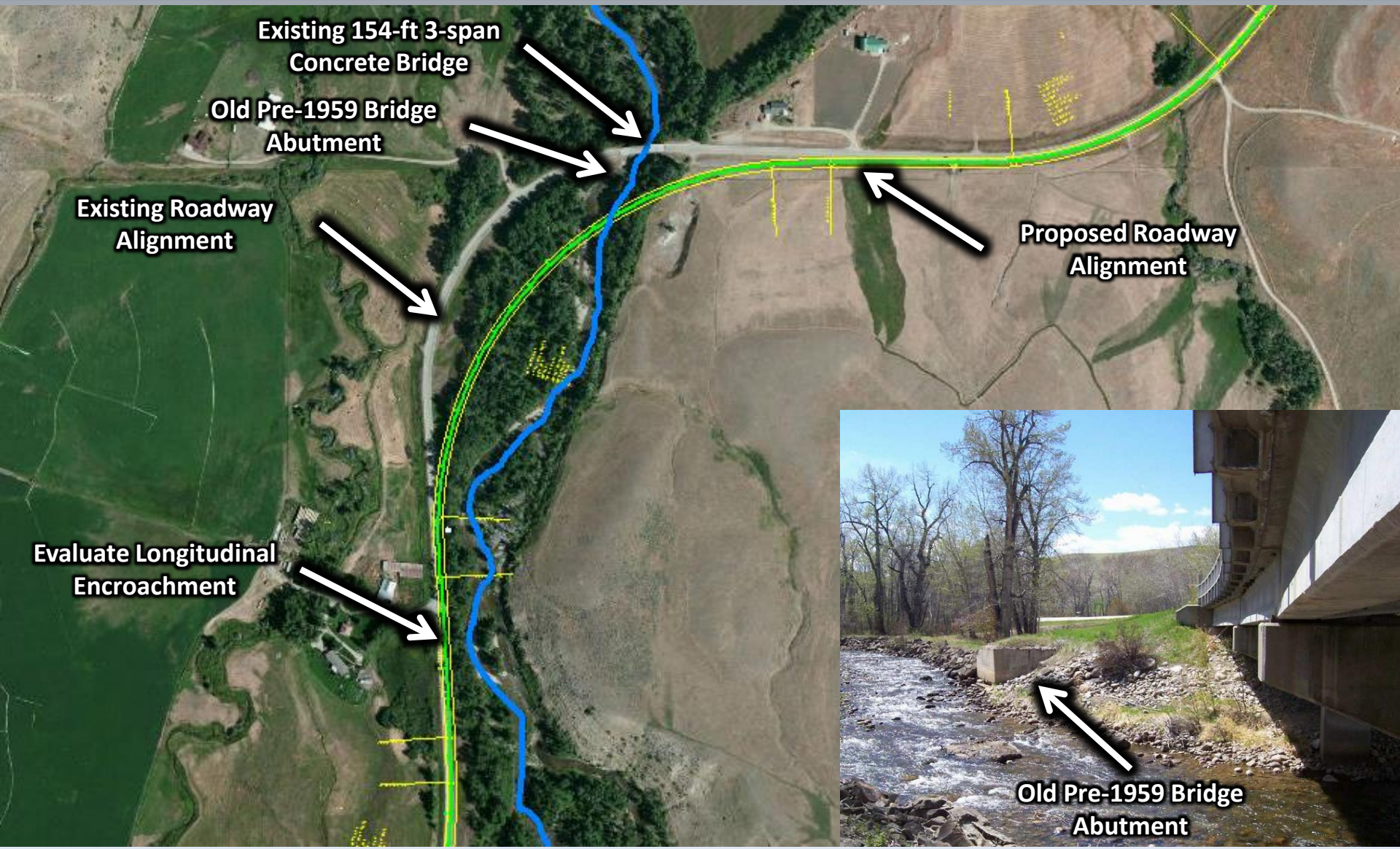


Lohman – East & West
Redrock Coulee Bridge Replacement

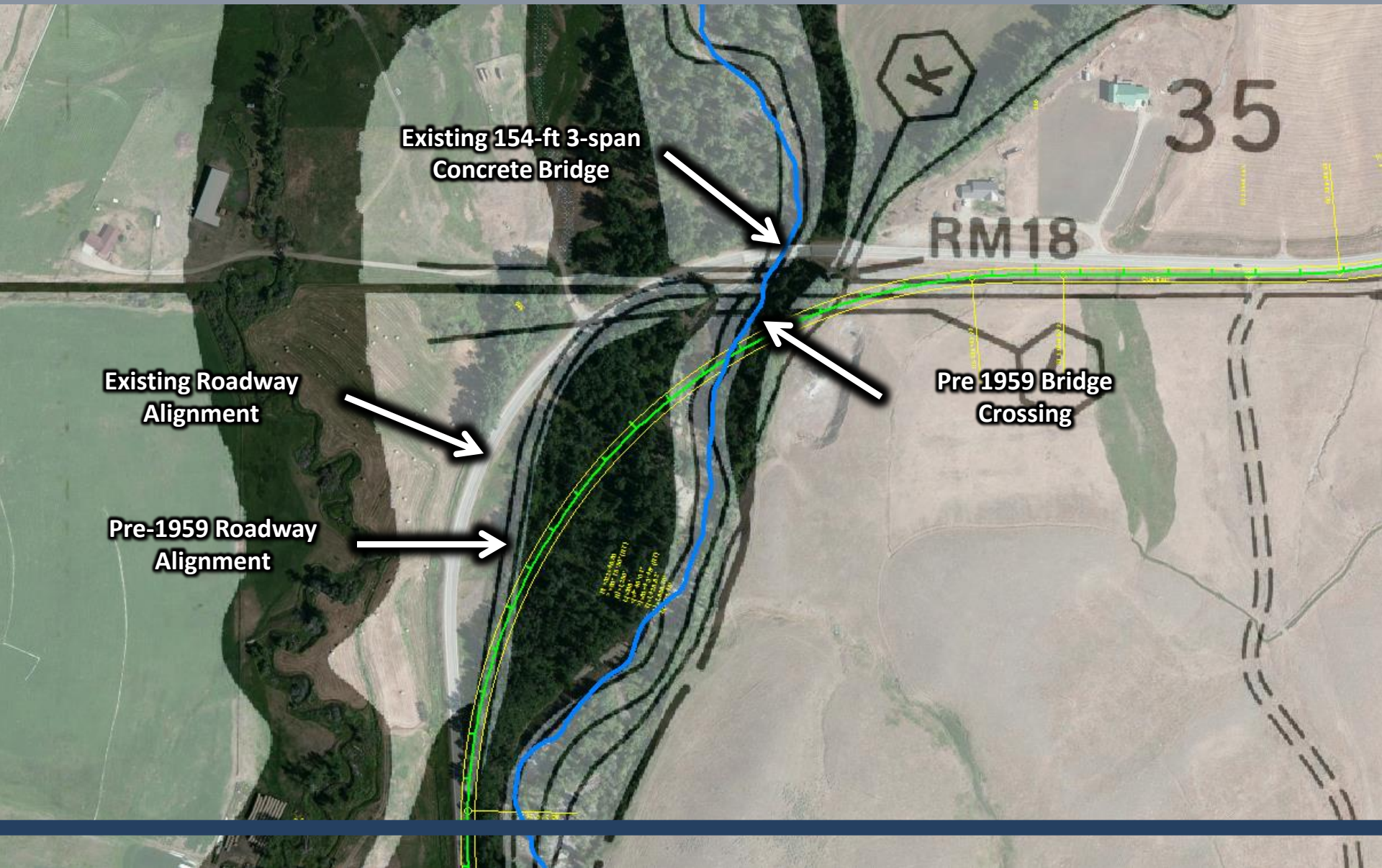
- **WHERE IS THE PROJECT TODAY:**
  - **All Hydraulic Models Are Complete for Red Rock Coulee**
    - **Models meet a No-Rise Condition Compared to the Existing Conditions:**
      - **Road Ditches Were Moved Due to Roadway Widening**
      - **Road Ditches Designed to Not Increase Existing WSEL**
      - **Re-Designed the Downstream Channel to Increase Flow Capacity**
      - **New Bridges Designed with Similar Hydraulics to Existing Bridges**
  - **The Project is in the Middle of Final Design and the Floodplain Permit will be submitted in the Near Future**



EAST ROSEBUD CREEK BRIDGE REPLACEMENT



EAST ROSEBUD CREEK BRIDGE REPLACEMENT



EAST ROSEBUD CREEK BRIDGE REPLACEMENT

- 1987 FIS STUDY
  - Indicated that the hydraulic models were completed in WSP-2, HUD-15 or HEC-2
  - No detailed documentation of the hydraulic analysis
- OBTAINED COPIES OF EFFECTIVE MODEL
  - HEC-2 input and results
  - Completed in 1980, After the 1959 Road Reconstruction

EAST ROSEBUD CREEK BRIDGE REPLACEMENT

- REPRODUCED HEC-2 INPUT FILE
  - Just came back from a conference that suggested recreating the HEC-2 input
- RAN THE INPUT FILE IN HEC-2
  - Results match exact! Great!

```
T1      STILLWATER COUNTY
T2      100 YR
T3      E. ROSEBUD

J1       ICHECK         INQ            NINV           IDIR           STRT           METRIC         HVINS          Q              WSF1           FQ
         0.000000       2.000000       0.000000       0.000000       0.000000       0.000000       3.000000       0.000000       4195.199       0.000000

J2       NPROF          IPLOT          PRFVS          XSECV          XSECH          FN             ALLDC          IBW      CHNIM          ITRACE
         1.000000       0.000000       -1.00000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000

J3       VARIABLE CODES FOR SUMMARY PRINTOUT
         110.0000       200.0000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000

NC       0.150000       0.200000       0.080000       0.300000       0.500000       0.000000       0.000000       0.000000       0.000000       0.000000
QT       2.000000       5354.000       5354.000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000
ET       0.000000       0.000000       5.400000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000


X1       201.0000       33.00000       40.00000       138.0000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000
GR       4200.000       0.000000       4194.699       40.00000       4189.500       55.00000       4192.000       80.00000       4192.098       110.0000
GR       4194.598       138.0000       4191.098       195.0000       4192.797       228.0000       4192.699       250.0000       4193.699       271.0000
GR       4193.898       378.0000       4192.297       388.0000       4193.699       409.0000       4192.699       448.0000       4193.000       543.0000
GR       4190.199       570.0000       4193.000       590.0000       4193.398       638.0000       4192.898       660.0000       4191.098       672.0000
GR       4190.898       680.0000       4191.699       690.0000       4189.500       700.0000       4191.199       730.0000       4192.797       740.0000
GR       4192.598       775.0000       4191.699       782.0000       4192.000       785.0000       4190.898       790.0000       4191.199       795.0000
GR       4193.500       800.0000       4193.500       830.0000       4196.797       870.0000       0.000000       0.000000       0.000000       0.000000
QT       2.000000       4760.000       4760.000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000


X1       202.0000       29.00000       817.0000       880.0000       460.0000       460.0000       460.0000       0.000000       0.000000       0.000000
X5       2.000000       4203.398       4203.898       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000       0.000000
GR       4210.000       519.9000       4210.000       520.0000       4204.098       530.0000       4202.199       570.0000       4202.297       750.0000
GR       4198.199       751.0000       4198.000       763.0000       4203.098       764.0000       4202.297       817.0000       4199.000       818.0000
GR       4196.598       826.0000       4196.199       846.0000       4196.898       851.0000       4196.398       856.0000       4196.398       861.0000
GR       4199.000       870.0000       4202.500       880.0000       4203.699       990.0000       4199.898       1000.000       4199.000       1005.000
GR       4200.000       1010.000       4200.598       1015.000       4200.598       1050.000       4203.598       1070.000       4204.500       1150.000
GR       4209.199       1230.000       4209.199       1500.000       4209.598       1700.000       4215.699       1830.000       0.000000       0.000000
```

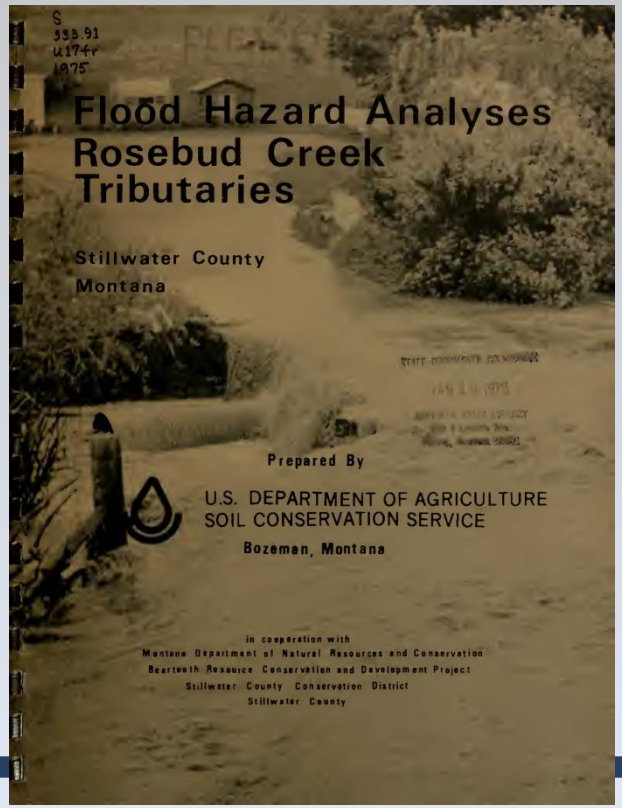
EAST ROSEBUD CREEK BRIDGE REPLACEMENT

- EXPORTED HEC-2 DATA INTO HEC-RAS
  - HEC-RAS model matches exactly the HEC-2 results
  - Great! Let's move on to Corrected Effective Model

- WORKING ON THE CORRECTED EFFECTIVE MODEL
  - The results for these cross sections weren't changing
  - What's going on?
  - Identified the flow file had set water surface elevations.
  - Remove them and the model didn't match report WSEL with 0.5-ft
  - Two different locations were over 2-ft from the reported numbers

EAST ROSEBUD CREEK BRIDGE REPLACEMENT

- PUT OUR INVESTIGATION HATS ON
  - Reviewed the HEC-2 Data and found the X5 Card in the Code
  - Research and found out there was 1975 SCS Flood Analysis
  - Coordinated with SCS Bozeman office to get report and the model results



EAST ROSEBUD CREEK BRIDGE REPLACEMENT

- INVESTIGATED THE SCS WSP-2 MODEL
  - WSEL hard enter in HEC-2 didn't match WSP-2 Results
  - Flow data in the HEC-2 model didn't match the WSP-2 Data
  - Model appears to model Post-1959 bridge
  - SCS Mapping shows Post-1959 bridge and roadway alignment
  - Redeveloped the WSP-2 model in HEC-RAS

EAST ROSEBUD CREEK BRIDGE REPLACEMENT

CSI CONCLUSION ON THE EFFECTIVE MODEL

- The effective model is the 1975 SCS WSP-2 model with updated design flows.
- It was assumed that at the time of the study, there was a requirement to use HEC-2 and this was the project specific decision that wasn't documented.
- The FIRM basemap was out of date and didn't reflect the existing roadway alignment.

DEVELOPED TWO DUPLICATE EFFECTIVE MODELS

- One using HEC-RAS
- Using the WSP-2 Model and new flows

DEVELOPED THE CORRECTED EFFECTIVE MODEL

- Incorporated additional cross sections

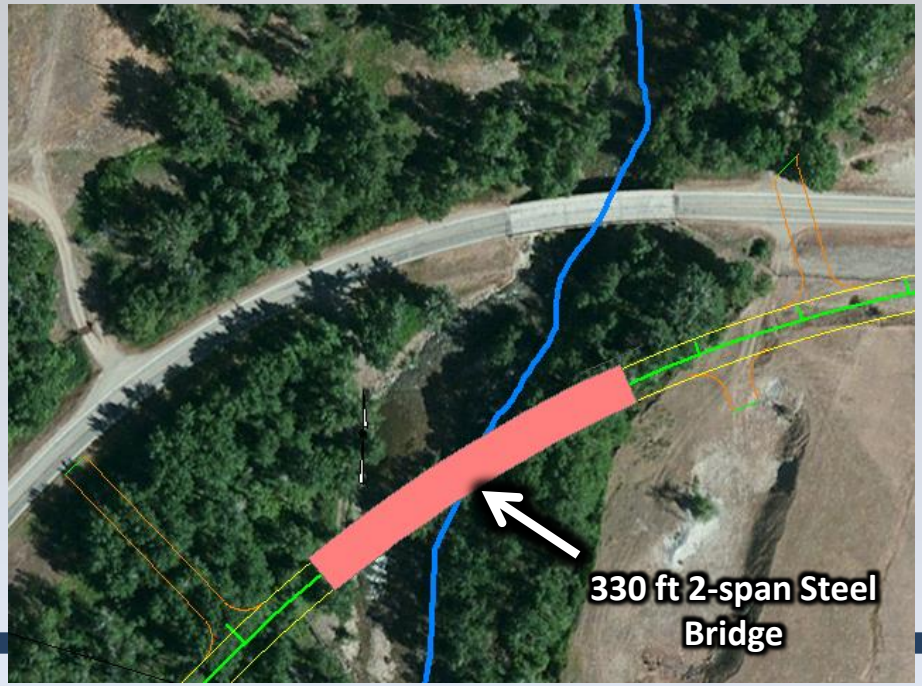
EAST ROSEBUD CREEK BRIDGE REPLACEMENT

- OTHER CORRECTIONS
  - Upgraded XS with more detailed topography
  - Change reach lengths
  - Change expansion and contraction coefficients
  - Add some ineffective flow areas
  - Revised bridge opening to better model pier blockage
- EXISTING CONDITIONS MODEL
  - Same as the Corrected Effective Model
- AFTER ALL THIS EFFORT, WE WERE FINALLY READY TO EVALUATE THE HYDRAULIC IMPACTS OF THE PROJECT

EAST ROSEBUD CREEK BRIDGE REPLACEMENT

➢ PROPOSED BRIDGE CROSSING

- ➢ 330-ft Two-Span Bridge
- ➢ Bridge is constructed within the backwater profile of the existing bridge
- ➢ Removal of the existing bridge and the Pre-1959 bridge abutment significantly reduces the backwater
- ➢ Proposed bridge provides a no-rise condition
- ➢ Upstream roadway embankment was re-designed to prevent hydraulic impacts



EAST ROSEBUD CREEK BRIDGE REPLACEMENT

➢ WHERE IS THE PROJECT AT TODAY?

- ➢ **Applied for the Floodplain Permit in 2013**
- ➢ **Received a Floodplain Construction Permit with conditions to complete a LOMR after construction in 2013**
- ➢ **Project is currently in the Right-of-way phase with an anticipating letting in 2017 or 2018.**

Key Points

- TECHNOLOGY IS A WONDERFUL THING
  - Better Data & More Refined Models
  - Electronic world has provided better way to manage data
- IT TAKES TIME TO DEVELOP MODELS
  - To document and compare the differences
- DOCUMENTATION IS IMPORTANT
  - Consider engineers 30-plus years from now will be looking at your work
  - A little more documentation would save a lot of time investigating.

Questions?

MONTANA MDT DEPARTMENT OF TRANSPORTATION

DOWL